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THE EFFECT OF KRAFT PULP AND PAPER MILL WASTES OF PEARL RIVER

Gerald N. McDermott

Environmental Health Center
Cincinnati, Ohio

October 1950

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October 1950

By

Gerald N. McDermott
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ABSTRACT

This report covers a short-time study of Pearl River pollution above and below confluence of Bogue Lusa and limited observation of the tributary Bogue Lusa during late October and early November, 1950. Bogue Lusa receives wastes from a kraft pulp and paper mill and untreated domestic sewage from Bogalusa, Louisiana.

Was es from the pulp and paper mill had a population equivalent of 350,000 (B.O.D. basis) with no bleach waste included. The Bogalusa sewered population was estimated at 15,000 people. There was virtually no change in the 5 day B.O.D. of this waste as it flowed through Bogue Lusa en route to Pearl River.

Bogue Lusa is a sluggish stream which allows deposition of suspended solids. Fiber loss from the pulp and paper mill was reported as 20 to 25 tons per day. A considerable tonnage of inert suspended solids were also lost from the chemical recovery system and the lime kiln stack gas wash. Results indicated that suspended solids were discharged to Pearl River from Bogue Lusa at the rate of 60 tons per day with an equal quantity settling out in the tributary. Pearl River bottom samples contained much organic matter including fiber.

During the period of this stream survey, Pearl River discharge varied between 2300 and 2900 c.f.s. Water temperatures were as low as 14°C. and as high as 22°C. Stream flow records indicate that on the average of once in ten years, Pearl River discharge may drop to 1250 c.f.s.

The lowest dissolved oxygen value recorded in the stream was 5.5 parts per million. During the week of highest water temperatures, the maximum oxygen depletion occurred in that section of the stream 18 to 24 miles be-

low the mouth of Bogue Lusa. Computations based on these observations indicate that dissolved oxygen may drop as low as 0.4 parts per million in a short stretch of Pearl River under adverse conditions. This low dissolved oxygen value presupposes simultaneous occurrence of the ten-year minimum flow of 1250 c.f.s. and a water temperature of 28°C.

The pulp and paper mill wastes increased the color approximately 15 to 18 parts per million. The color persisted in spite of oxidation of most of the organic matter present. Sulfides were not detected following dilution of the wastes in the river.

The biological study revealed that bottom life in Pearl River below Bogue Lusa discharge had been decidedly affected by pollution. Clean water organisms such as Mayfly nymphs and unionid clams apparently disappeared completely below Bogalusa where certain pollution-tolerant forms were abundant. More extensive observations of the distribution, relative abundance, condition, and food habits of important fish species, in both the polluted and unpolluted water, would be necessary for reaching firm conclusions concerning the effect of the pollution on fish population.

This study reveals information making possible predictions that at times when flow is low and water temperatures high oxygen depletions below that generally recognized as necessary for maintenance of desirable game fish species are likely to occur. Unusually heavy waste loads due to malfunctioning of equipment and cleanups at critical flow times provide a definite threat to aquatic life. Likewise purging and scouring of deposited paper mill waste materials in Bogue Lusa by flash storms may conceivably add sufficient pollutional matter to Pearl River to cause damage to aquatic life.

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INTRODUCTION

Expansion of the sulphate pulp and paper industry in the south in recent years has intensified waste disposal problems. Under the responsibilities of Public Law 845, 80th Congress, to participate in the study of and contribute to the solution of industrial waste disposal problems, the Public Health Service undertook, in 1949, a program to study the problems of kraft mill wastes in cooperation with the industry. One phase of this program was study of the effects of kraft pulp and paper mill wastes on a receiving stream. At conferences between representatives of the industry, state agencies, and the Public Health Service, the Pearl River below Bogalusa, Louisiana, was selected for the initial stream study. Factors influencing selection of the Pearl were: the stream is relatively unpolluted except for waste of the kraft industry; complaints alleging objectionable pollution of the Pearl River had been received by State agencies; and the stream is inter-state.

GENERAL INFORMATION

1. Organization of Survey

This investigation was conducted by the Environmental Health Center of the Public Health Service, with assistance from the Louisiana Stream Control Commission, Gaylord Container Corporation, and the National Council for Stream Improvement of the pulp, paper and paperboard industry. Analytical determinations were carried out in mobile laboratory units and in the control laboratory of the mill. Gaylord Container Corporation furnished utility connections for the mobile units, conducted preliminary

reconnaissance to acquaint survey personnel with the river, and made available waste flow records. Louisiana Stream Control Commission supplied boats for river sampling, and a biologist who assisted with the biological studies.

2. Dates of Survey

The survey was conducted during October and November, 1950. Samples were collected on nine sampling days as follows: October 23 through October 27, November 6 through November 9.

3. Personnel

Personnel participating in preliminary meeting at which this study was arranged, in planning conferences, and conduct of the survey, include the following:

GAYLORD CONTAINER CORPORATION
- Vertrees Young, Executive Vice-President and Resident Manager
- Alfred Suter, General Superintendent
- W. F. Gillespie, Technical Director
- J. J. Goss, Assistant Technical Director
- A. R. Haarala, Chemist
- A. E. Reed, Chemical Engineer
- F. C. Ratliff, Chemical Engineer
- J. E. Sapp, Chemical Engineer

LOUISIANA STREAM CONTROL COMMISSION
- Frank J. Coogan, Technical Adviser
- Robert A. Lafleur, Biologist

NATIONAL COUNCIL FOR STREAM IMPROVEMENT
- Dr. H. W. Gehm, Technical Advisor
- W. A. Moggio, Southern Resident Engineer and Project Leader

U. S. PUBLIC HEALTH SERVICE
L. F. Warrick, Chief, Technical Services Branch, WPC
M. LaBosquet, Jr., Director of Field Activities, EHC
H. H. Black, Chief, Industrial Waste Section, EHC
M. B. Ettinger, Scientist, EHC
Peter Doudoroff, Biologist, EHC
W. W. Walker, Chemist
Carl N. Shadix, Chemist
G. N. McDermott, S. A. Sanitary Engineer
Albert L. Platz, J. A. Sanitary Engineer
S. D. Pinkoski, Physical Science Aide

4. Purpose

The purpose of this study was to determine the effect of kraft pulp and paper mill waste on the receiving stream in an endeavor to ascertain the capacity of natural waters to assimilate such wastes.

5. Description of Pearl River below Bogue Lusa

Pearl River rises in east central Mississippi and flows south 475 miles, discharging through several mouths into the coastal sounds of the Gulf of Mexico. This study was concerned with the river from the waste source at the entrance of the tributary known as Bogue Lusa to near the river mouth. Figure 1 is a map of this section. In this region, the river follows a tortuous course through heavily timbered bottom lands. The river has a wide flood plain varying in width from 2 to 5 miles, and contains many bayous and dead channels.

Between the mouth of Bogue Lusa, river mile 72.4, and a point near upper Walkiah Bluff, the channel averages about 200 feet in width. The banks are 5 to 11 feet above low water except where occasional bluffs rise to heights of about 18 feet. The so-called bluffs are placed where the stream meanders to the edge of the flood plain and has cut into the

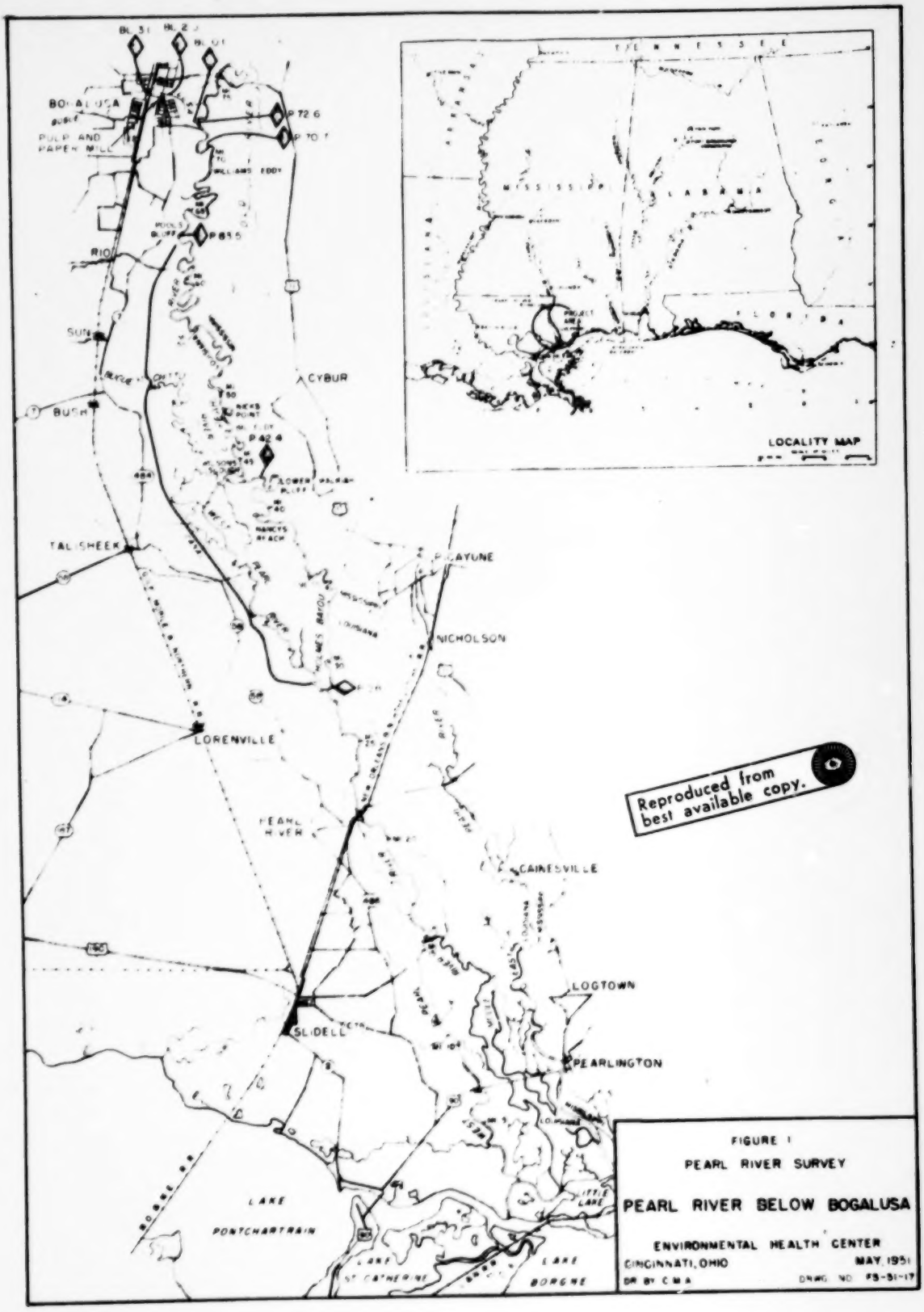

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FIGURE 1

PEARL RIVER SURVEY

PEARL RIVER BELOW BOGALUSA

ENVIRONMENTAL HEALTH CENTER

CINCINNATI, OHIO MAY 1951

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point of the adjacent uplift. At discharges occurring during the survey, the midchannel water depths averaged about 8 feet. There are very few shallow sections or deep holes. Just below the mouth of Bogue Lusa, for a distance of ess than 1/2 mile, is a large pool in which the depth of water exceeds 20 feet. The average velocity in this entire 25 mile length of the river is about 1.4 miles per hour at the flow stages prevailing during this survey. A small ou -flowing channel exists at mile 45.8; this channel was carrying less than 10 cubic feet per second at the time of the survey.

At river mile 44.3, the channel divides with an estimated 1/3 to 1/2 of the water flowing to the west through a deep, narrow channel known as Wilson's Slough. This chan el is a mile or more in length, and enters the channel known as the West Pearl River. The main channel continues for another few miles to the former junction with th channel known as Ea t Pearl River, mile 31.8.

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About 1850, East Pearl River became congested by a jamke raft of logs to such a state that the stream was forced through a small slough known as Holmes Bayou. As a part of a navigation improvement project, started in 1880, a dam was built across the river channel at the junction of Holmes Bayou. As a result of the log jam and the dam, the Bayou was enlarged to such an extent that the en ire low water discharge of the Pearl River above now flows through it. The former junction at present is hardly distinguishable, and the East Pearl River drains only a small local area below this point, except during the high water season hen the overflow from other branches find its way into this channel. The ection of the Pearl River below where the flow divides, and particularly Holmes Bayou, is especially winding with somewhat swifter average current. Also the channel is generally

narrower, a eraging about 140 feet. Holmes Bayou joins the West Pearl River at river mile 27.7. West Pearl River, at this junction, contains not only the water which flows to it from the point where the Pearl divides, but also considerable water from the tributary known as Bogue Chitto. Below the junction with Holmes Bayou, the West Pearl divides into several channels, the main flow remains in the channel known as West Pearl, which discharges into the Rigolets, one of the outlets of Lake Pontchartrain. East Pearl discharges to Lake Borgne. This length of the West Pearl is less winding than upstream sections of the Pearl and it is, in general, considerably wider. For 26 miles above the mouth, West Pearl River is tidal, and has little slope at low water.

Bogue Chitto is a tributary of appreciable size. Its minimum flow of record being 480 cfs. It empties into the West Pearl River near its head through several channels. Bogue Chitto, West Pearl and Wilson Slough have a network of interconnecting channels.

Bogue Lusa is a small tributary entering the Pearl River from the west at river mile 72.4. Low flow of this stream was about 50 cfs. during the survey.

A project of the U. S. Army, Corps of Engineers, was undertaken beginning in 1938, to provide a channel suitable for six-foot navigation from the mouth of West Pearl River to the city of Bogalusa, Louisiana. Considerable of the project was completed by 1942 when work was interrupted. Work toward completing the project was resumed in November 1950. The project includes, in addition to natural channel improvement, the construction of a lateral canal, seven feet deep and eighty feet wide, extending 20.1 miles through the bottom lands west of the river from the mouth of Holmes Bayou to Peel's Bluff about nine miles below Bogalusa. Two dams or sills

in the river channel just below Pool's Bluff and across Bogue Chitto are also called for in the project. The sills, together with three locks in the canal, will maintain water level in the canal and river. At the time of the survey, construction of the sills had not commenced, but the canal and locks were complete except for the upstream few hundred feet connecting the canal and river. Only lock water an gate leakage will be allowed to pass through the canal.

6. Source of Waste

A large integrated kraft pulp and paper mill discharges its waste to a small tributary of the Pearl River known as Bogue Lusa, at a point 2.4 miles above the junction of he stream with Pearl River. The city of Bogalusa, which has an estimated sewered population of 15,000, also discharges its untreated domestic sewage to Bogue Lusa through two main outfalls. These sewers enter Bogue Lusa in the reach between the plant outfall and the mouth. A few individual household septic tanks and private sewers from a section of the city enter a small tributary of Pearl iver known as Coburn Creek. Coburn Creek enters the Pear about a mile above Bogue Lusa. Bogue Lusa, above the mill, receives no sewage or i t rial waste pollution.

Pulp and paper making at Bogalusa, Louisiana, dates from 1917. The original mill of that date was an integrated unit designed for the production of sixty tons of sulfate pulp and 105 tons of liner board daily. Subsequent additions to the mill capacity were made in 1920, 1925, 1927, and 1931. In 1931, the semi-chemical pr cess for hardwoods was initiated at the mill.

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A major expansion occurred in 1940 with the installation of a high-speed Fourdrinier paper machine which about doubled paper making capacity. This program included new boilers, generator, and recovery furnace installation, plus a counter-current pulp washing system for handling part of the pulp. In addition, as a part of the 1940 program, a bleach plant designed for 150 tons daily capacity was installed. This bleach plant, however, was not operated during this survey, and has operated only intermittently since 1946. In 1948, installations to augment pulp capacity to balance potential paper making capacity were completed. These included four new digestors, a new barker, chipper, chip screens, recovering furnace, bins, lime kiln, boiler, generator, and additional washers and pulp thickeners. Additions to and improvements of evaporators were accomplished and a Cottrell precipitator for the recovery unit was installed. The daily capacity of the mill is 700 tons of sulfate pulp, 100 tons of semi-chemical pulp, and waste paper handling capacity of 100 tons. This permits an over-all daily production of approximately 900 tons, airdry basis, of all grades. The paper mill produced from 700 to 915 tons of paper daily during the survey. A considerable range of products is manufactured. During the survey, products made included filled and chip grade boards, Fourdrinier and cylinder liner board, corrugat ng board, bag, wrapping, and laminated paper. This production, and, therefore, the maximum waste load of the mill has probably dated from 1948. When the bleach plant is operating, higher waste loads prevail than during the survey.

SURVEY METHODS

7. Chemical Studies

The characteristics of waters of the Pearl River just above and for 45

miles below the mouth of Begue Lusa were determined by chemical analysis of samples of the water. Determinations made were as follows: temperature, dissolved oxygen, immediate oxygen demand, biochemical oxygen demand, pH, alkalinity, color, sulfides, and solids. A discussion of the significance of each of these determinations is contained in the appendix.

Sample Collection

Samples were collected for dissolved oxygen determinations with standard dissolved oxygen samplers which minimized aeration of the sample. The samples were stored above ice during transport to the laboratory for analysis. The dissolved oxygen samples were collected in duplicate in the field, one bottle was analyzed for dissolved oxygen on being received at the laboratory, the other sample was incubated for B.O.D. analysis. Samples from the river were collected from boats at approximate mid-stream and mid-depth. Maximum time elapsing between collection and analysis was about 8 hours. Samples for sulfide determinations were collected in separate bottles which contained zinc acetate solution which precipitated the sulfide and prevented its oxidation or escape and also prevented further sulfide generation.

Sampling Points

Samples for the routine analysis were collected at 5 stations on the Pearl River, from 3 stations on the Begue Lusa, and during part of the survey, from the sewer outfalls of the plant. Stream sampling points are shown on Figure 1, and are tabulated below:

Sampling Station Designation	Stream	Miles Above Mouth	Miles Below Mouth of Bogue Lusa
BL 3.1	Bogue Lusa	3.1	——
BL 2.5	" "	2.5	——
BL 0.1	" "	0.1	——
P 72.6	Pearl River	72.6	——
P 70.7	" "	70.7	1.7
P 63.5	" "	63.5	8.9
P 42.4	" "	42.4	30.0
P 28	" "	28	44.4

In addition to the routine samples, several sampling trips on the river were made for the purpose of establishing the state of oxygen depletion at numerous points on the river. Samples were collected at 3-mile intervals throughout a 30 to 50 mile stretch of the river.

Laboratory Procedures

Laboratory procedures were those prescribed in "Standard Methods for the Examination of Water and Sewage" by the American Public Health Association, and the American Water Works Association, except for the oxygen consumed determination. The dichromate reflux method was used for determination of oxygen consumed as described in the American Chemical Society publication "Analytical Chemistry," Volume 21, p. 953, August, 1949.

8. Biological Studies

Some biological observations were made on the Pearl River above and at points up to 45 miles below the mouth of Bogue Lusa. Attention was concentrated on the bottom fauna but a limited fish and plankton study was included.

Sample Collection

Bottom samples were taken with a Petersen dredge. Net plankton samples were taken by dipping up about 20 to 25 gallons of water in mid-stream, and

straining t through a Wisconsin-type plankton net. A mall straight seine was used for collection of ish.

9. Hydrographic Procedures

Approximate flow in Bogue Lusa were obtained by establishing gaging stations above the water intake of the paper mill and below the outfall sewers.

The flow in Pearl River was obtained from the United States Geological Survey, which organization maintain a gaging station at Highway 35 bridge, river mile 75.6. With the exception of Bogue Lusa, tributary flow to the stream was considered to be negligible in the length sampled.

RESULTS

10. Chemical Studies

The average of results obtained dur ng the first five days of the survey, Octo er 23 to October 27, are presented in Table 1. Also included in Table 1 are the average results obtained during the sampling period, November 6 to November 10. Differences in water temperatures makes averaging together the results of both periods inadvisable. During the latter period, an unusually high waste load occurred for an extended period on Novembe and 8. n the tabulation of average results during this period, values considered to be influenced by the unusual waste load were omitted. A tabulation of individual results is contained in the appendix.

The results of samples taken at frequent intervals along the river for dissolved oxygen depletion studies are given in Table 2, and are shown graphically in Figure 2.

A tabu ation of individual results is contained in the appendix.

TABLE 1 - AVERAGE DETERMINATIONS - PEARL RIVER

Station	Discharge cfs	Temp. °C.	Dissolved Oxygen ppm	Dissolved Oxygen % Sat.	5-day, 20°C. B.O.D. ppm	5-day, 20°C. B.O.D. lbs/day	Immediate Oxygen Demand ppm	Oxygen Consumed ppm	pH Range	Alkalinity MO ppm	Sulfides Total as S ppm	Color ppm	Total ppm	Vol
First Sampling Week														
BL 3.1	40	20	7.8	84	1.0	184			6.5-6.7	21	<0.1	35	86.8	36
BL 2.5	51	34	0		214	58700	13.2	666	9.3-9.5		1.2	650	1585	7
BL 0.1	51	31	0		222	60900	17.6	715	7.9-9.2		1.9	760		
P 72.6	2480	20	7.9	87	0.8	10300		15	6.3-6.7	16	<0.1	35	66.9	22
P 70.7	2535	20	7.3	80	3.9	52300		33	6.7-8.5	26		50	83.9	33
P 63.5	2535	21	6.1	68	3.2	43800		31	7.0-7.2	29		55		
P 42.4		21	6.1	68	1.6	18800		28	6.8-7.2			43		
P 28		21	6.8	78	1.1	15500			6.6-7.2	24		52		
Second Sampling Week														
Total Plant Wastes	46				236	57800	20	1030	8.3-9.4	1016		950	2184	9
BL 0.1		28	0		176		8	574	7.4-9.0	276	0.8	738	887	4
P 72.6	2851	16	9.2	92	0.9	12800		15	6.5-6.7	16		30	72	
P 70.7	2903	16	8.6	87	4.4	68800		28	7.3-7.5	25		45	102	
P 63.5	2900	16	7.6	77	3.7	57700			7.1-7.2	23		45		
P 42.4		16	7.2	72	2.2	33700			6.9-7.0	23		35		
P 28		17	8.1	84	1.6	24500			6.9-7.1	22		35		

TABLE 1 - AVERAGE DETERMINATIONS - PEARL RIVER SURVEY

	Oxygen Consumed ppm	pH Range	Alkalinity MO ppm	Sulfides Total as S ppm	Color ppm	TOTAL SOLIDS				Suspended Solids		Dissolved Solids	
						Total ppm	Volatile ppm	Total 100 #/day	Volatile 100 #/day	Total ppm	Volatile ppm	Total ppm	Volatile ppm
		6.5-6.7	21	<0.1	35	86.8	36.1	16.3	7.1	24.5	15.4	62.3	20.7
2	666	9.3-9.5		1.2	650	1585	779	435	214	1051	520	534	259
6	715	7.9-9.2		1.9	760								
	15	6.3-6.7	16	<0.1	35	66.9	22.7	898	308				
	33	6.7-8.5	26		50	83.9	33.7	1149	405				
	31	7.0-7.2	29		55								
	28	6.8-7.2			43								
		6.6-7.2	24		52								
	1030	8.3-9.4	1016		950	2184	956	530	233	918	596	1166	360
	574	7.4-9.0	276	0.8	738	887	476			434	291	453	185
	15	6.5-6.7	16		30	72	25	1114	384	31.6	29.3		
	28	7.3-7.5	25		45	102	41	1593	646				
		7.1-7.2	23		45					34.4	25.7		
		6.9-7.0	23		35								
		6.9-7.1	22		35								

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Table 2 - Results of Oxygen Depletion Sampling Runs

	October 25, 1950				October 27, 1950				November 6, 1950			
Flow in Pearl R. below Bogue Lusa	2520 cfs				2283 cfs				2914 cfs			
Sampling Station	Dissolved Oxygen ppm	Dissolved Oxygen % Sat	Temp °C	5-Day 20°C BOD ppm	Dissolved Oxygen ppm	Dissolved Oxygen % Sat.	Temp °C	5-Day 20°C BOD ppm	Dissolved Oxygen ppm	Dissolved Oxygen % Sat.	Temp °C	5-Day 20°C BOD ppm
P 72.6	7.9	86	20	0.6	8.0	86	19	0.8	8.8	85	14	1.0
P 70.7	7.0	76	20	3.6	7.1	77	20	5.0	8.6	85	15	4.8
P 69.7	6.6	72	20	3.1	7.1	77	20	4.1	8.4	83	15	4.7
P 66.5	6.3	70	21	2.8	6.4	70	20	3.6				
P 63.5	6.1	68	21	2.8	5.8	63	20	3.7	7.9	78	15	3.2
P 60.5	5.8	64	21	2.6	5.9	66	21	4.5	7.7	77	16	3.0
P 57.5	5.6	62	21	2.3	6.0	67	21	3.8	7.5	75	16	3.0
P 54.5	5.6	62	21	2.5	6.2	69	21	2.4	7.5	75	16	2.7
P 51.5	5.7	63	21	2.8	5.8	64	21	2.7	7.4	74	16	2.5
P 48.5	5.5	61	21	1.7	5.6	62	21	2.6	7.4	74	16	2.1
P 45.5	5.7	63	21	1.7	5.9	66	21	2.0	7.3	73	16	2.3
P 42.4	5.9	66	21	1.2	6.4	71	21	2.2	7.0	70	16	2.4
P 39.5												
P 36.5												
P 33.5												
P 30.5												
P 28	7.1	79	21	1.4					7.4	74	16	1.9

Table 2 continued on next sheet

Table 2 (Cont'd) - Results of Oxygen Depletion Sampling Runs

	November 7, 1950				November 9, 1950			
Flow in Pearl R. below Bogue Lusa	2921 cfs				2882 cfs			
Sampling Station	Dissolved Oxygen ppm	% Sat	Temp °C	5-Day 20°C BOD ppm	Dissolved Oxygen ppm	% Sat	Temp °C	5-Day 20°C BOD ppm
P 72.6	9.5	98	17	0.8	9.1	90	15	0.7
P 70.7	8.8	90	17	4.6	8.5	85	16	3.8
P 69.7					8.0	80	16	3.3
P 66.5								
P 63.5	7.7	79	17	3.5	7.2	71	15	3.4
P 60.5					7.0	69	15	2.8
P 57.5					7.0	69	15	3.3
P 54.5					7.0	69	15	3.5
P 51.5					6.6	65	15	2.8
P 48.5					6.6	65	15	3.4*
P 45.5					6.4	63	15	4.1*
P 42.4	7.3	72	15	1.7	5.5	54	15	4.5*
P 39.5	7.6	75	15	1.6				
P 36.5	7.7	76	15	1.5				
P 33.5	7.7	77	16	1.4				
P 30.5	7.9	79	16	1.4				
P 28	8.0	82	17	1.2	8.4	88	18	2.0*

* Results high due to unusual waste load at mill.

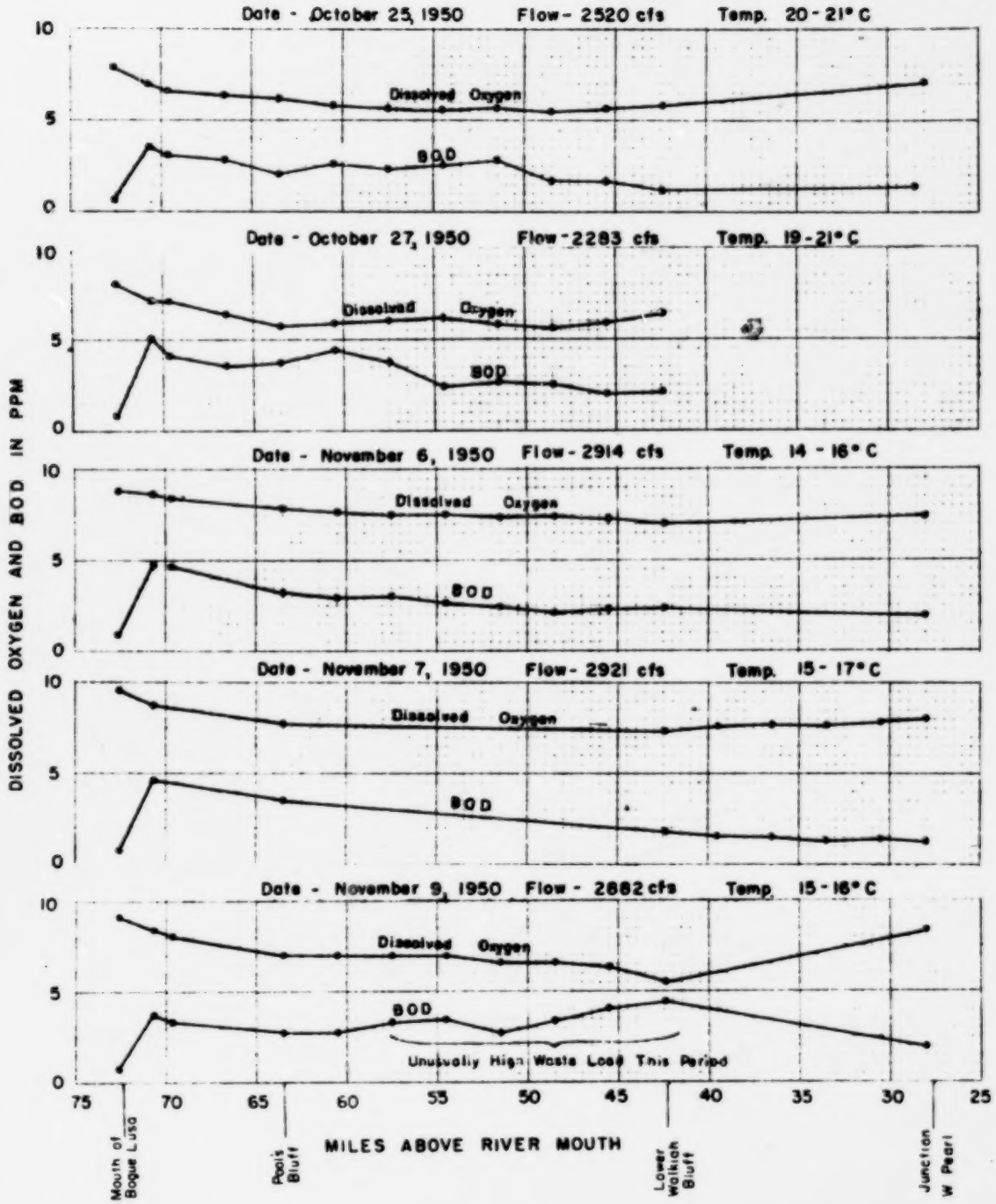

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FIGURE 2
PEARL RIVER SURVEY
DISSOLVED OXYGEN PROFILE

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CINCINNATI, OHIO MAY, 1951
DR BY G N M DRWG NO FS-51-18

As far as the small creek, Bogue Lusa, is concerned, from the plant outfall to Pearl River, during non-flood stages, it is nothing more than a channel carrying the wastes and city sewage in a practically undiluted state to the river. This section, particularly near the mouth, contains deep beds of deposited fibers, bark particles, and mineral silt. The mineral silt is from the lime kiln stack gas wash and undissolved material, called "dregs," from the chemical recovery operation. Anaerobic digestion of the organic material produces a continuous boiling effect as the generated gases rise in bubbles to the surface. Numerous mats of the organic material, buoyed by gas bubbles, float into the river.

Biochemical Oxygen Demand

The results of sampling Bogue Lusa during the first week show an addition of about 58,500 pounds of 5-day BOD at the mill outfalls and 60,900 pounds carried in the stream as it empties into the Pearl. This indicates that no apparent reduction is accomplished in this short stream length. The results from sampling the total plant wastes, during the second week, verify closely the stream sampling BOD loads with an average of 57,800 pounds of 5-day BOD.

Pearl River above Bogue Lusa had a quite low BOD, averaging only 0.8 ppm. This content probably originates from natural vegetative matter in the stream's sources. Sampling at 1.7 miles below the mouth during the first week showed 52,300 pounds of 5-day BOD; subtracting that upstream from Bogue Lusa indicates a load of 42,000 pounds. During the second week, samples from the Pearl River above and below showed 55,700 pounds as being added by Bogue Lusa. The first sample was taken 1.7 miles below for the purpose of insuring a well-mixed sample; this mileage was sufficiently long, considering the rapid rate of oxidation, to reduce the load an appreciable percentage. Preliminary

testing showed that satisfactory mixing of the wastes in the stream waters occurred upstream from this point.

On a parts-per-million basis, the waste load and upstream BOD figure indicates that the 5-day BOD content just below the mouth would average about 5 ppm. In comparing results on the river during the first and second sampling weeks, agreement should not be expected in results of samples collected any distance downstream considering the temperature difference. During the first sampling week, the BOD averaged 3.9 ppm at station 70.7, 1.7 miles below the mouth of Bogue Lusa. This appears to be slightly lower than would be expected from the data obtained on the waste load. This is probably due to variations inherent in the BOD test, and in sampling. Nine miles below, at Pool's Bluff, the BOD was reduced to an average of 3.2 ppm and at Lower Walkiah Bluff, 30 miles below, the average was 1.6 ppm.

Immediate Oxygen Demand

The samples from Bogue Lusa, below the mill and at the mouth, had an appreciable immediate oxygen demand; individual samples at this station, had from 0 to 34 ppm. Total plant waste composite samples had from 7.5 to 17.0 ppm.

Dissolved Oxygen

The lowest value observed was on a sample taken on the oxygen depletion sampling run of October 25. This value was 5.5 ppm. During the temperature and flow conditions prevailing during the first sampling week, the maximum oxygen depletion was in the stretch from 18 to 24 miles below the mouth of Bogue Lusa.

During the colder temperatures of the second sampling week, oxygen depletions were considerably less severe. Maximum depletion was to 6.9 ppm and the maximum depletion occurred about 30 miles from the mouth of Bogue Lusa.

Solids

Considering total solids, the results during the first sampling week show that the mill wastes added 419,000 pounds of total solids to Bogue Lusa, about half of which were volatile. This compares with 514,000 pounds obtained from sampling the total plant wastes during the second sampling week. Volatile solids agree quite closely, 207,000 to 226,000 pounds respectively. Sampling of Pearl River below and above Bogue Lusa, during the first sampling week, show that 251,000 pounds of total solids were added to the river, 157,000 pounds of which were volatile. Results of sampling the Pearl above and below Bogue Lusa during the second week show 479,000 pounds of total solids added to the river, 262,000 pounds of which were volatile. These figures on solids entering the river are not in close agreement due to possible variations in solids content of the wastes or other causes, such as scour. The settling-out of some material in Bogue Lusa is, from physical inspection, an obvious fact. Much of the solids in this waste is the mineral silt which probably does settle out to consi r ble extent in Bogue Lusa. In addition, bark particles and fiber are in evidence in heavy sludge deposits in that stream. None of these materials has an appreciable effect on 5-day BOD.

Suspended solids in the samples taken from Bogue Lusa above and just below the mill outfalls, during the first sampling week, indicated an average of about 280,000 pounds of suspended solids discharged daily by the mills. Samples of total plant wastes, during the second sampling week, indicated that an average

of about 230,000 pounds of suspended solids are discharged daily. The results from samples taken during the second sampling week at the mouth of Bogue Lusa, showed about 120,000 pounds of suspended solids discharged to Pearl River. These figures indicate that approximately 50 per cent of the suspended solids settled out in Bogue Lusa. Analysis of composite samples of plant wastes for pulp loss as performed by the paper mill technical staff indicated an average daily loss of about 50,000 pounds of pulp fiber during the first sampling week, and 40,000 pounds during the second. Much of the suspended solids is evidently the mineral matter previously mentioned. Pearl River bottom samples, taken up to 30 miles below Bogue Lusa during the biological study, as discussed later, were reported as containing much organic matter, including some wood fiber.

Much of the material deposited in Bogue Lusa is probably flushed into the Pearl River during high water in Bogue Lusa. With this thought in mind, samples from the sludge beds above the mouth of Bogue Lusa were collected and BOD tests carried out on the filtrate. These tests indicated the filtrate to contain about 1,000 ppm BOD. Thus, there is a definite possibility that a high BOD load could be flushed to Pearl River by a flash flood in Bogue Lusa.

Sulfides

Sulfides were present in Bogue Lusa below the mill outfall in amounts averaging 1.2 ppm expressed as sulfur (S) and, in the stream as it entered the Pearl, sulfides averaged 1.9 ppm. Anaerobic conditions which prevail in Bogue Lusa evidently were accompanied by the production of some sulfides. Sulfides were not detected in Pearl River samples, which fact is consistent with the small amount present in Bogue Lusa water.

Color

Some interesting phenomena were observed in relation to color. The wastes

were highly colored, averaging 950 ppm in total plant wastes. Pearl River, above Bogue Lusa, already possessed an appreciable color content, 33 ppm, probably from vegetable matter on the watershed; however, the wastes did increase color to 51 pp below Bogue Lusa. This color persisted and even increased slightly in the stream during the next 45 miles. Maintenance of color, in spite of a major reduction in the BOD, indicates that the color compound is not subject to biological oxidation, or that the oxidized form of the compound is at least as intensely colored as the original form. This phenomenon has been reported on other streams and in biological treatment of the wastes.

11. Biological Studies

The pollution prevalent in a stream may be judged on a biological basis from a study of the character and population of organisms present. Many plants and animals found in clean water are exacting in their habitat requirements, while others are more tolerant or even prefer a bottom of high organic content. Under conditions of heavy pollution, the former group must migrate or die; the latter, for whom these conditions and the absence of many competitors and predators are favorable, may build up huge populations characteristic of certain pollution zones. They thus serve as clues to the intensity of pollution, or the degree of recovery. In judging the degree of pollution, the aquatic biologist does not depend upon any single species, but rather on ecological groups or communities and the relative abundance of sensitive and tolerant or pollutional forms in the total population. Bottom organisms, especially those which move only short distances and which have

a long life cycle, are of value for indicating pollution conditions over considerable periods of time. By their use, severe conditions prior to the survey can be detected, and something of the pollutional history of the stream during the past year determined. The presence of organisms which serve as food for desirable fish species is essential for the maintenance of valuable fish populations.

Bottom Sampling

Preliminary observations made above Bogue Lusa showed that in this stream and elsewhere where the current was swift, the bottom was of coarse sand and gravel and was quite barren. Thereafter, bottom samples were taken only near the banks at depths of 2 to 10 feet, and only where the bottom was fairly soft, consisting of silt, clay and fine sand. Twelve such samples, believed to be representative of the various types of bottom materials, were taken with a Petersen dredge in the Pearl River between the mouth of the Bogue Lusa and a point 3 1/2 miles upstream. These samples invariably contained burrowing mayfly nymphs (Hexagenia sp.) The numbers of these organisms ranged from 9 to 100 per sample, and averaged more than 40 per sample. Unionid clams of several species and widely varying size were present in nine (75 per cent) of these samples. A total of 19 such clams, and also 9 gill-breathing operculate snails (Viviparus sp.) were found. A majority of the samples also contained oligochaete worms and small chironomid (midge) or other dipteran larvae, but these organisms were not numerous in any of the samples. A few dragonfly nymphs and leeches also were found.

Twenty-six comparable bottom samples were taken below the source of pollution, at a distance of about 1 to 2-1/2 miles (6 samples), 9 miles (near Pool's Bluff: 7 samples), 30 miles (near Lower Walkiah Bluff: 7 samples), and 43 miles

(in Holmes Bayou near Lock #1: 6 samples) downstream from the mouth of Bogue Lusa. No mayfly nymph or operculate snail was found in any of these samples, and only one clam was found in one of the samples taken about 30 miles below the source of pollution. Oligochaete worms (turbificids) and minute chironomid larvae, on the other hand, were numerous, and some air-breathing, pulmonate snails were present in some of these samples, particularly those taken about 1 to 9 miles below the source of pollution, where "sewage fungus" (Sphaerotilus) also grew in profusion. Much more organic material, including gelatinous masses of "sewage fungus," wood fiber and detritus, was present in most of these samples than in those taken above the mouth of the Bogue Lusa. Because of the difficulty of separating from this material all of the very numerous small worms and minute chironomids present in some of the samples, a count of these organisms was judged impracticable. At the sampling points farthest downstream, the bottom was comparatively barren, both the pollutional forms and the clean water forms found elsewhere being scarce or absent.

Six bottom samples were taken in the West Pearl River. This river contains a portion of the waters of the Pearl that has received the pulp and paper mill wastes, and considerable additional water from Bogue Chitto, which is practically unpolluted. The samples were taken at a distance of only a fraction of a mile from the lowermost sampling station mentioned above (in Holmes Bayou, near Lock #1). Because of the swift current and other features of the stream, no entirely satisfactory samples of soft bottom, comparable with most of the samples taken elsewhere, could be obtained in the West Pearl River. Nevertheless, one or more mayfly nymphs

(Hexagenia) were present in three of the samples taken. In all, 6 mayfly nymphs as well a 4 dragonfly nymphs and a few smaller animals, were found. One Petersen dredge sample and one Ekman dredge sample taken in a slough connecting with the Pearl River a short distance above the Bogue Lusa contained 26 mayfly nymphs, 19 very small clams, and several other organisms.

Plankton

Net plankton samples were taken both above and at distances of about 9 and 30 miles below the source of pollution. In the latter samples, wood fibers were numerous, and some fragments of Sphaerotilus and a few other organisms were found. True plankton organisms were lacking at all sampling points, however, so that further study of the plankton was judged to be of no value. Plankton organisms apparently are of littl or no importance in this fairly swift stream.

Fish Seining

Some small cyprinids (minnows or shiners) were taken in Pearl River above the mouth of Bogue Lusa. A larger number of cyprinids of several species as well as young channel catfish and small flounder were taken near Pool's Bluff, about 9 miles below the source of pollution. Forage fishes were apparently quite plentiful here.

Discussion

The biological study reveals that the bottom life in the Pearl River below Bogalusa has been decidedly affected by pollution. Clean water organisms such as mayfly nymphs and unionid clams, which were common above the source of pollution, apparently disappeared completely below the source, where certain pollution-tolerant forms were abundant. There is evidence that the detrimental effect of pollution on the clean water organisms extended downstream for a

distance of at least 43 miles, beyond which no observations were made. Pollutional organisms, on the other hand, apparently were much less numerous in the lower portion of the polluted stream section studied than in the upper portion. Thus, no stimulating or beneficial effect on the production of bottom-living organisms was apparent below the most markedly polluted zone.

The destruction, in the polluted zone, of the normal population of clean-water bottom-living organisms may well be detrimental to some desirable fish species which depend on it as a source of food. The pollutional conditions noted are not generally regarded as being conducive to good game-fish p oduction. However, some tolerant bottom-living organisms and small forage fishes which can serve as food for large predaceous game species, such as black bass, were plentiful well within the markedly polluted zone, and some food-fish were present also. A decidedly detrimental effect of pollution on the food supply and fish production in this zone cannot be assumed. There is evidence of impairment of the food supply farther downstream, where strikingly pollutional conditions were lacking. The biological observations reported here are of a preliminary nature. A more extensive investigation, including studies of the distribution, relative abundance, condition and food habits of important fish species, in both the polluted and unpolluted water, would have to be undertaken in order to reach definite conclusions concerning the effect of the pollution on fish production.

12. Extension of BOD and Dissolved Oxygen Data to Conditions of Lower Flow and Higher Temperatures

The ability of a stream to assimilate pollution without damage due to oxygen depletion is dependent to a large extent upon its flow and the strength and volume of the waste it receives. Water temperature is of importance; it has a dual

effect on oxygen depletion of a stream. The amount of oxygen capable of being dissolved in water varies with the temperature; the higher the temperature, the less oxygen the water will hold in solution. Higher temperatures also increase the activity of bacteria and other organisms in their process of utilizing the oxygen in the stream for oxidizing organic matter, resulting in more rapid oxygen use. In a stream, this latter factor is offset to a large degree by greater rates of surface reaeration at the higher temperatures.

Thus conditions of highest temperature and lowest discharge, would be expected to be associated with maximum oxygen depletions, assuming a constant waste load. The combinations of conditions producing oxygen depletion sufficient to damage aquatic life may occur on the average of only once in five years or once in twenty years, etc. Nevertheless, short duration oxygen depletion conditions may deleteriously affect the biological life of a stream for many months. It is not practical to approach pollution abatement from the standpoint of taking samples and obtaining data during such infrequently occurring periods. Data gathered during less severe depletion conditions must be used as a basis for predicting what dissolved oxygen conditions will prevail at times of lower flows and higher temperatures.

It follows that knowledge of the magnitude and frequency of occurrence of lower flows in the stream during high temperature months is necessary. Using stream flow records, methods are available for predicting the low flows which can be expected to occur on the average of once in five, ten, or twenty years or whatever period is selected (1) (2). Specifically, stream flow records are available for the Pearl River over a period of 10 years. July, August, and September were considered the high water temperature months. Records of low flows during these months were analyzed and the following predictions made:

Values in cubic feet per second which the flow may be expected to qual or to be less than on the average of once in:

2 years - 1790 cfs
5 years - 1470
10 years - 1250

A second factor of importance is the high water temperature which might be reached. No data are available on high temperatures occurring in Pearl River; however, data from other streams in the vicinity indicate that 28° C. water temperatures may occur.

One method of predicting oxygen depletion is dependent upon using a mathematical equation which has been evolved for expressing the oxygen depletion phenomena or oxygen sag curve. Values of the exponential functions of this equation are obtained from the B.O.D. and dissolved oxygen data of the survey. This formula is based on the principle that under any certain set of conditions the rate of biological oxidation is a function of the concentration of the biochemical oxygen demanding substances, and the rate of r aeration is dependend upon the oxygen deficiency in the stream. The exponential functions change value with temperature; methods employed for compu ing these changes were found in referen e (3). This method of approach yielded information that the minimum dissolved oxygen expected to occur on the average of once in ten years, at 1250 cfs flow and 28° C. water temperature, would be 0.4 ppm.

Many uncertainties are involved in making such predictions; indeed the phenomena of oxygen depletion in streams is influenced by factors so numerous as to defy exact computations. Nevertheless these predictions can be used to conclude that the normal pollution lead to Pearl River is such that depletion of the dissolved oxygen level below that generally recognized as necessary for

maintenance of desirable game fish species is likely to occur during low flow and high temperature periods of a frequency of every few years. The occurrence of unusually heavy waste loads from the mill at times of malfunctioning of equipment or clean-ups reinforce contentions that aquatic life destruction by oxygen depletion is a real possibility. Such an unusually high waste load occurred during the survey on November 7 and November 8. On those dates a breakdown of equipment in the chemical recovery system resulted in greatly increased B.O.D. loads to the sewers through overflow of black liquor and resin acid soaps from storage tanks. Stream grab samples showed B.O.D. loads over 4 times greater than normal during this spill. If similar high waste loads were to occur during times of low flow and high temperature the dissolved oxygen would be reduced in a stretch of the river to concentrations such that serious distress and possible destruction of aquatic life would be likely. Another explanation of aquatic life damage claims is the possibility that a flash flood in Bogue Lusa would carry deposits of paper mill waste materials, which accumulate during low flows, to Pearl River in the form of a slug which could cause a high load of pollutants to enter the river over a short period.

Attention is also called to the fact that the bleach plant of the mill was not operating at the time these observations were made. Bleach plant wastes might increase waste loads appreciably.

REFERENCES

(1) Velz, C. J., "Utilization of Natural Purification Capacity in Sewage and Industrial W s e Disposal." Sewage and Industrial Wastes, V. 22, p. 1601, (1950).

(2) Gumbel, E. J., "Flood Flows by the Probability Method." Eng. News-Rec., 134, 97, (1945).

(3) Gotaas, Harold B., "Effect of Temperature on Biochemical Oxidation of Sewage". Sewage Works Journal, V. 22, p. 441, (1948).

(4) LaBosquat, M., Jr., Tsivoglou, E. C., "Simplified Dissolved Oxygen Computations." Sewage and Industrial Wastes, V. 22, p. 1054 (1950).

APPENDICES

APPENDIX A

APPENDIX A

SIGNIFICANCE OF LABORATORY DETERMINATIONS

Dissolved Oxygen

Oxygen dissolves in water to a slight extent. The quantity of the dissolved gas the water contains at saturation depends considerably upon the temperature, being 9.17 parts per million at 20°C, 8.38 at 25°, etc. Fish and much other aquatic life depend on oxygen dissolved in water for the oxygen used in their life processes; the minimum quantity for sustenance of desired fish species is considered to be 5 ppm. Dissolved oxygen is used by bacteria, omnipresent in stream waters, in their oxidation of organic matter contained in the water to produce energy for growth and metabolism. If dissolved oxygen is removed by such action faster than it is absorbed from the air a deficit of oxygen below saturation values will result. Thus dissolved oxygen values below the saturation level are an indication of the presence of organic pollution.

Biochemical Oxygen Demand (BOD)

The biochemical oxygen demand of polluted water or industrial wastes is the amount of oxygen required during stabilization of the organic matter by aerobic bacterial action. Since this is a phenomenon into which both time and temperature enter, a standard set of conditions (5 days, 20° C) is universally used for the test. For domestic sewage and some industrial wastes, approximately 68 per cent of the oxygen requirement of the carbonaceous material present is normally satisfied during the standard test. For industrial wastes with certain characteristics different from domestic sewage, this per cent satisfied during the test may differ considerably.

The BOD test is indicative of deoxygenation which will occur in natural waters which receive the waste. Oxygen deficiencies result in distress to fish

and depletions result in noxious odor production.

Immediate Oxygen Demand

Certain compounds may be present in wastes or waters containing no dissolved oxygen which when placed in contact with oxygen combine with it in a short time. Oxygen utilized by a waste or polluted water within 15 minutes of mixing with water containing dissolved oxygen is termed immediate oxygen demand.

Temperature

The temperature of water controls the oxygen solubility and thus saturation level of dissolved oxygen in the stream. The rate of natural purification by bacterial growth is increased with higher temperatures and decreased with lower.

Oxygen Consumed from Dichromate

The oxygen consumed test is a measure of the chemical oxidant required to oxidize the organic matter present in a sample under particular standardized conditions. It is expressed as parts per million oxygen. The test is of value in estimating the strength of certain industrial wastes, and in conjunction with the determination of the B.O.D. It can be used where it would be advantageous to obtain results indicative of B.O.D. strengths in less time than the B.O.D. test requires.

Solids

Solids analyses include those for total solids, suspended solids, and the volatile constituents of each. Total solids consist of all the solids present in a liquid, the term includes both suspended solids and dissolved solids. Suspended solids are in suspension or float on the surface of water, sewage, or other liquid, and are removed by laboratory filtering. Dissolved solids are found by subtracting suspended solids from total. Volatile solids are those that are lost upon ignition of total solids (giving total volatile solids) or suspended solids (giving volatile suspended solids). Suspended solids

cause water to be turbid and unsightly. Suspended solids may settle on the bed of the receiving body of water, with formation of sludge banks. Volatile solids are ordinarily a measure of organic matter.

Color

Color is determined by comparison with solutions of known concentrations of potassium chloroplatinate. It is expressed on a parts per million basis. Color due solely to substances in solution was determined, as the suspended matter was removed by centrifuging before the color determination.

Color is objectionable in domestic and certain industrial water supplies. It is difficult to remove. In streams, color is objectionable on aesthetic grounds and may adversely affect aquatic life through reduction of light transmission.

pH

The symbol "pH" denotes the logarithm of the reciprocal of the hydrogen ion concentration. It is a measure of acidity or basicity but is not directly proportional to the amount of acid or base present. The pH is significant for its influence on biological decomposition, and on chemical treatment processes. Extreme ranges of pH in streams may affect aquatic life and increase costs of treatment of water.

Alkalinity

Alkalinity of a water or a waste is usually caused by the presence of carbonates, bicarbonates, hydroxides, and less frequently by borates, silicates, and phosphates. Alkalinity is determined by neutralization of these compounds with and to certain equivalence points as given by indicator solutions. Phenolphthalein,

or its equivalent, is used for one of these points and methyl orange, or its equivalent, for the other. Alkalinity is expressed as calcium carbonate, parts per million basis. The discharge of a waste of high alkalinity into a watercourse may be of concern when such water is used as a source of domestic, industrial, or irrigation water.

Sulfides

Total sulfides, which includes all dissolved sulfides and also acid-soluble metallic sulfides present as suspended matter, were determined. Hydrogen sulfide, which was likely to have been one form of sulfide present, is readily oxidized by any oxygen which may be in the water and thus exerts an immediate oxygen demand. It has been reported that concentration of the gas in water in minute concentrations are lethal for fish. Hydrogen sulfide escapes rapidly to the atmosphere from water surfaces. It is a colorless gas which, in low concentrations, has an offensive odor described as that of rotten eggs. The characteristic odor of the gas is detectable in concentrations as low as 0.025 ppm, it is distinct at 0.3 ppm, and is intensively offensive at 3 to 5 ppm. Hydrogen sulfide gas reacts with the pigments of lead base paints and darkens them. It is considered a factor in the disintegration of concrete. Mercaptans have also been found in these wastes and are included in the determination. Methyl mercaptan has been reported as being toxic to fish in a concentration as low as 0.5 ppm. Mercaptans are highly volatile, and have an extremely offensive odor even at extraordinarily minute concentrations.

APPENDIX B

APPENDIX B - INDIVIDUAL DETERMINATIONS - PEARL RIVER SU

Date 1950	Discharge cfs	Temp °C	Dissolved Oxygen ppm	Dissolved Oxygen % Sat.	5-Day 20° B.O.D. ppm	5-Day 20° B.O.D. lbs/day	Immediate oxygen demand ppm	Oxygen Consumed ppm	pH	Alkalinity MO ppm	Sulfides Total as S ppm	Color ppm	TOTAL Total ppm	TOTAL Volatile ppm
Station BL 3.1 - Bogue Lusa above mill outfall, 3.1 miles above junction with Pearl River														
10/23	36	21	7.5	83	0.7	136			6.5	15	<0.1	40	89.0	49.0
10/24	45	19	7.6	81	0.6	145			6.5	23	<0.1	35	59.0	8.5
10/25	37	20	7.8	85	1.4	279			6.7	14	<0.1	35	72.0	32.5
10/26	41	18	8.0	84	0.8	176			6.5	16	<0.1	35	88.0	47.2
10/27		20	8.0	87	1.6	-			6.7	37	<0.1	30	126.4	43.2
Avg.	40	20	7.8	84	1.0	184				21	<0.1	35	86.8	36.1
Station BL 2.5 Bogue Lusa below mill outfall, 2.5 miles above junction with Pearl River														
10/23	47	32	0		204	51700	7.5	653	9.3		2.0	450	1860	866
10/24	55	33	0		179	53000	14.5	606	9.5		1.5	625	1772	868
10/25	56	34	0		207	62500	16.5	658	9.3		0.1	625	1032	502
10/26	52	34	0		189	53000	10.5	566	9.4	853	2.0	700	1288	588
10/27	47	35	0		290	73500	17.0	845	9.4		0.7	800	1982	1032
Avg.	51	34	0		214	58700	13.2	666			1.2	650	1585	779

...DIX B - INDIVIDUAL DETERMINATIONS - PEARL RIVER SURVEY

...	Oxygen Consumed ppm	pH	Alkalinity MO ppm	Sulfides Total as S ppm	Color ppm	TOTAL SOLIDS Total ppm	TOTAL SOLIDS Volatile ppm	TOTAL SOLIDS Total 1000#/Day	TOTAL SOLIDS Volatile 1000#/Day	SUSPENDED SOLIDS Total ppm	SUSPENDED SOLIDS Volatile ppm	DISSOLVED SOLIDS Total ppm	DISSOLVED SOLIDS Volatile ppm
...l miles above junction with Pearl River													
		6.5	15	<0.1	40	89.0	49.0	17.3	9.5	29.6	11.6	59.4	37.4
		6.5	23	<0.1	35	59.0	8.5	14.3	2.1	2.8	2.8	56.2	5.7
		6.7	14	<0.1	35	72.0	32.5	14.3	6.5	11.6	8.4	60.4	24.1
		6.5	16	<0.1	35	88.0	47.2	19.4	10.4	32.0	15.0	56.0	32.2
		6.7	37	<0.1	30	126.4	43.2			46.0	38.8	80.4	4.4
			21	<0.1	35	86.8	36.1	16.3	7.1	24.5	15.4	62.3	20.7
... miles above junction with Pearl River													
	653	9.3		2.0	450	1860	866	471	220	1318	520	542	346
	606	9.5		1.5	625	1772	868	525	258	1288	568	484	300
	658	9.3		0.1	625	1032	502	312	152	584	372	448	130
	566	9.4	853	2.0	700	1288	588	360	164	748	416	540	172
	845	9.4		0.7	800	1982	1032	502	261	1316	724	666	306
	666			1.2	650	1585	779	435	214	1051	520	534	259

B

APPENDIX B - INDIVIDUAL DETERMINATIONS - PEARL RIVER S

Date 1950	Discharge cfs	Temp °C	Dissolved Oxygen ppm	Dissolved Oxygen % Sat.	5-Day 20° B.O.D. ppm	5-Day 20° B.O.D. lbs/day	Immediate Oxygen Demand ppm	Oxygen Consumed ppm	pH	Alkalinity MO ppm	Sulfides Total as S ppm	Color ppm	TOTA Total ppm	TOTA Volati ppm
Total Plant Wastes - composite sample from two outfall sewers and lime s wer														
11/6	46.6				247	62000	10.5	797	9.2	490		900	1346	68
11/7	44.4				224	53500	29	1370	8.3	1640		1000	3022	123
11/8	46.0				750*	186000	0*	1610*	9.4*	482*		1625*	1886*	116
11/9	47.0				380*	96100	15*	1040*	8.9*	447*		875*	1400*	74
Average	46				236	57800	20	1030		1016		950	2184	95

* Not considered in average because of unusual waste load.

A

B - INDIVIDUAL DETERMINATIONS - PEARL RIVER SURVEY

Oxygen Con-sumed ppm	pH	Alkal-inity MO ppm	Sul-fides Total as S ppm	Color ppm	TOTAL SOLIDS				SUSPENDED SOLIDS		DISSOLVED SOLIDS	
					Total ppm	Volatile ppm	Total 1000#/Day	Volatile 1000#/Day	Total ppm	Volatile ppm	Total ppm	Volatile ppm
m two outfall sewers and lime s wer												
797	9.2	490		900	1346	682	338	172	716	456	630	226
1370	8.3	1640		1000	3022	1230	722	294	1120	736	1902	494
1610*	9.4*	482*		1625*	1886*	1160*	468*	288*	730*	526*	1156*	634*
1040*	8.9*	447*		875*	1400*	748*	354*	189*	1268*	1048*		
1030		1016		950	2184	956	530	233	918	596	1166	360

e of unusual waste load.

APPENDIX B - INDIVIDUAL DETERMINATIONS - PEARL RIVER SU

Date 1950	Discharge cfs	Temp. °C	Dissolved Oxygen ppm	Dissolved Oxygen % Sat.	5-Day 20° B.O.D. ppm	5-Day 20° B.O.D. lbs/day	Immediate Oxygen Demand ppm	Oxygen Consumed ppm	pH	Alkalinity MO ppm	Sulfides Total as S ppm	Color ppm	TOS Total ppm	TOS Volati ppm
Station HL 0.1 - Bogue Lusa at junction with Pearl River														
First Sampling Week														
10/23	47	32	0		165	41800	10	702	9.2		1.5	750		
10/24	55	31	0		203	60100	12.5	495	8.4		1.5	750		
10/25	56	32	0		192	57900	19.5	572	7.9		2.6	750		
10/26	52	31	0		214	60000	11.5	695	8.3	539	2.0	750		
10/27	47	30	0		>334	84500	34.5	1120	8.5		2.0	800		
Average	51	31	0		222	60900	17.6	715			1.9	750		
Second Sampling Week														
11/6	50**	27	0		177		5	581	9.0	273	0.6	875	892	466
11/7	50**	30*	0		796*		0*	1510*	7.4*	306*	0.8*	800*	1442*	820
11/8	50**	31*	0		810*		5*	1630*	9.3*	486*	1.2*	1000*	1602*	1010
11/9	50**	30	0		175		10	568	7.7	280	1.2	600	882	486
Average		28	0		176		8	574		276	0.8	750	887	476

* Not considered in average because of unusual waste load.

** Estimated.

K B - INDIVIDUAL DETERMINATIONS - PEARL RIVER SURVEY

Oxygen Consumed ppm	pH	Alkalinity MO ppm	Sulfides Total as S ppm	Color ppm	TOTAL SOLIDS				SUSPENDED SOLIDS		DISSOLVED SOLIDS	
					Total ppm	Volatile ppm	Total 1000#/Day	Volatile 1000#/Day	Total ppm	Volatile ppm	Total ppm	Volatile ppm
ver												
702	9.2		1.5	750								
495	8.4		1.5	750								
572	7.9		2.6	750								
695	8.3	539	2.0	750								
1120	8.5		2.0	800								
715			1.9	750								
581	9.0	273	0.6	875	892	466	241	126	420	224	472	242
1510*	7.4*	306*	0.8*	800*	1442*	820*	388*	221*	358*	344*	1084*	476*
1630*	9.3*	486*	1.2*	1000*	1602*	1010*	432*	273*	780*	552*	822*	458*
568	7.7	280	1.2	600	882	486	238	131	448	358	434	128
574		276	0.8	750	887	476	240	128	434	291	453	185

unusual waste load.

B

APPENDIX B - INDIVIDUAL DETERMINATIONS - PEARL

Date 1950	Discharge cfs	Temp °C	Dissolved Oxygen ppm	Dissolved Oxygen % Sat.	5-Day 20° B.O.D. ppm	5-Day 20° B.O.D. lbs/day	Immediate Oxygen Demand ppm	Oxygen Consumed ppm	pH	Alkalinity MO ppm	Sulfides Total as S ppm	Color ppm	Tota ppm
Station P 72.6 Pearl River, mile 72.6, just above junction with Pearl River													
First Sampling Week													
10/23	2826	22	7.8	88	0.81	12200			6.6	16	<0.1	40	74.
10/24	2568	20	7.9	86	0.73	9700		13	6.5	16	<0.1	35	63.
10/25	2464	20	8.0	87	0.64	8630		20	6.3	9	<0.1	30	61.
10/26	2326	20	8.0	87	0.71	8800		14	6.7	20		35	67.6
10/27	2236	19	8.0	86	0.84	10000		14	6.7	18	<0.1	35	67.6
Average	2480	20	7.9	87	0.8	9900		15		16		35	66.9
Second Sampling Week													
11/6	2864	14	8.8	85	1.0	15400		25	6.7	16		25	71
11/7	2871	17	9.5	98	0.8	12400		10	6.7	15		35	82
11/8	2838	17	9.4	96				13	6.7	17		30	65
11/9	2832	15	9.1	90	0.7	10700		10	6.5	14		37	72
Average	2851	16	9.2	92	0.9	12800		15		16		30	72

A

NDIX B - INDIVIDUAL DETERMINATIONS - PEARL RIVER SURVEY

me-iate Oxygen ygen Con-mand sumed ppm	Oxygen Con-sumed ppm	pH	Alkal-inity MO ppm	Sul-fides Total as S ppm	Color ppm	TOTAL SOLIDS Total ppm	TOTAL SOLIDS Volatile ppm	TOTAL SOLIDS Total 1000#/Day	TOTAL SOLIDS Volatile 1000#/Day	SUSPENDED SOLIDS Total ppm	SUSPENDED SOLIDS Volatile ppm	DISSOLVED SOLIDS Total ppm	DISSOLVED SOLIDS Volatile ppm
e junction with Pearl River													
		6.6	16	<0.1	40	74.8	35.2	1140	535				
	13	6.5	16	<0.1	35	63.2	12.4	877	172				
	20	6.3	9	<0.1	30	61.2	22.8	813	303				
	14	6.7	20		35	67.6	23.2	847	291				
	14	6.7	18	<0.1	35	67.6	20.0	814	241				
	15		16		35	66.9	22.7	898	308				
	25	6.7	16		25	71	27	1097	417	18.4	16.4		
	10	6.7	15		35	82	22	1270	340	21.8	21.8		
	13	6.7	17		30	65	25	994	382				
	10	6.5	14		37	72	26	1096	396	54.6	49.8		
	15		16		30	72	25	1114	384	31.6	29.3		

B

APPENDIX B - INDIVIDUAL DETERMINATIONS - PEARL R

Date 1950	Discharge cfs	Temp. °C	Dissolved Oxygen ppm	Dissolved Oxygen % Sat.	5-Day 20° B.O.D. ppm	5-Day 20° B.O.D. lbs/day	Immediate Oxygen Demand ppm	Oxygen Consumed ppm	pH	Alkalinity MO ppm	Sulfides Total as S ppm	Color ppm	Total ppm
Station P 70.7 Pearl River at Mile 70.7, 1.7 miles below mouth of Bogue Lusa													
First Sampling Week													
10/23	2873	22	7.5	85	3.7	57200			6.7	24	<0.1	50	86.4
10/24	2623	20	7.5	82	2.8	39500		49	8.5	33	<0.1	55	82.0
10/25	2520	20	7.0	76	3.6	48800		22	7.2	23	<0.1	45	90.4
10/26	2378	20	7.2	78	4.2	53800		23	7.3	28		50	80.8
10/27	2283	20	7.1	78	5.0	62000		39		23	<0.1	55	80.0
Average	2535	20	7.3	80	3.9	52300		33		26		50	83.9
Second Sampling Week													
11/6	2910	15	8.6	85	4.8	75200		31	7.3	27		40	95
11/7	2920	17	8.8	90	4.6	72300		24	7.3	22		55	103
11/8	2890*	17*	8.4	86	7.5	116000		51*	7.5	27*		55*	105*
11/9	2880	16	8.5	85	3.8	58800		29	7.3	27		45	108
Average	2903	16	8.6	87	4.4	68800		28		25		45	102

* Not considered in average due to unusual waste load.

ENDIX B - INDIVIDUAL DETERMINATIONS - PEARL RIVER SURVEY

...e-ate Oxygen ...gen ...mand ppm	Oxygen Consumed ppm	pH	Alkalinity MO ppm	Sulfides Total as S ppm	Color ppm	TOTAL SOLIDS Total ppm	TOTAL SOLIDS Volatile ppm	TOTAL SOLIDS Total 1000#/Day	TOTAL SOLIDS Volatile 1000#/Day	SUSPENDED SOLIDS Total ppm	SUSPENDED SOLIDS Volatile ppm	DISSOLVED SOLIDS Total ppm	DISSOLVED SOLIDS Volatile ppm
es below mouth of Bogue Lusa													
		6.7	24	<0.1	50	86.4	45.2	1338	700				
	49	8.5	33	<0.1	55	82.0	21.2	1160	300				
	22	7.2	23	<0.1	45	90.4	40.8	1230	555				
	23	7.3	28		50	80.8	34.0	1036	436				
	39		23	<0.1	55	80.0	27.2	984	334				
	33		26		50	83.9	33.7	1149	465				
	31	7.3	27		40	95	41	1488	642				
	24	7.3	22		55	103	39	1618	617	15.4	14.8		
	51*	7.5	27*		55*	105*	55*	1634*	855*	22.2	9.4		
	29	7.3	27		45	108	44	1673	682				
	28		25		45	102	41	1593	646				

e unusual waste load.

B

APPENDIX B - INDIVIDUAL DETERMINATIONS - PEARL RIVER S

Date 1950	Discharge cf	Temp. °C.	Dissolve Oxygen ppm	Dissolve Oxygen % Sat.	5-Day 20° B.O.D. ppm	5-Day 20° B.O.D. lbs/day	Immediate Oxygen Demand ppm	Oxygen Consumed ppm	pH	Alkalinity MO ppm	Sulfides Total as S ppm	Color ppm	TOTAL S Total ppm	TOTAL S Volati pp
Station 63.5 Pearl River, mile 63.5, at Pool's Bluff, 9 miles below mouth of Bogue Lusa														
First Sampling Week														
10/23	2873	22	6.2	71	2.6	40100		29	7.1	30	<0.1	55		
10/24	2623	22	6.0	68	3.3	46600		30	7.0	28	<0.1	60		
10/25	520	21	6.1	68	2.8	38000		37	7.2	29	-	50		
10/26	2378	22	6.2	70	3.8	48700		27	7.2	32	<0.1	50		
10/27	2283	20	5.8	63	3.7	45500			7.	27		50		
Average	25	21	6.1	68	3.2	43800		31		29		55		
Second Sampling Week														
11/6	2910	15	7.9	78	3.2	50200			7.2	25		35		
11/7	2920	17	7.8	80	3.5	55000			7.2	20		45		
11/8	2890	18	7.5	79	4.7	73000			7.1	23		50		
11/9	2880	15	7.2	71	3.4	52700			7.1	23		45		
Average	2900	16	7.6	77	3.7	57700				23		45		

B - INDIVIDUAL DETERMINATIONS - PEARL RIVER SURVEY

Oxygen Con-sumed ppm	pH	Alkal-inity MO ppm	Sul-fides Total as S ppm	Color ppm	TOTAL SOLIDS				SUSPENDED SOLIDS		DISSOLVED SOLIDS	
					Total ppm	Volatile ppm	Total 1000#/Day	Volatile 1000#/Day	Total ppm	Volatile ppm	Total ppm	Volatile ppm
7. 9 miles below mouth of Bogue Lusa												
29	7.1	30	<0.1	55								
30	7.0	28	<0.1	60								
37	7.2	29	-	50								
27	7.2	32	<0.1	50								
	7.	27		50								
31		29		55								
	7.2	25		35								
	7.2	20		45					14.2	13.8		
	7.1	23		50					23.8	8.2		
	7.1	23		45					66.2	55.0		
		23		45					34.4	25.7		

B

APPENDIX B - INDIVIDUAL DETERMINATIONS - PEARL RIVER SU

Date 1950	Discharge fs	Temp. °C.	Dissolved Oxygen ppm	Dissolved Oxygen % Sat.	5-Day 20° B.O.D. ppm	5-Day 20° B.O.D. lbs/day	Immediate Oxygen Demand ppm	Oxygen Consumed ppm	pH	Alkalinity MO ppm	Sulfides Total as S ppm	Color ppm	TO Total ppm	TO Volati ppm
Station 42.4 Pearl River, Mile 42.4, a lower Walkiah Bluff 30 miles below mouth of Bogue Lusa														
First Sampling Week														
10/23	21	6.1	68		1.8	16400*			7.0	28	<0.1	55		
10/24	20	6.1	66		1.5	21100*			6.8	21	<0.1	60		
10/25	21	5.9	65		1.2	15700*			7.2	34		50		
10/26	20	6.2	68		1.1	14300*			7.1	30		50		
10/27	21	6.4	71		2.2	26600*								
Average	21	6.1	68		1.6	18800*				28		43		
Second Sampling Week														
11/6	16	7.4	74		1.9	30400*			7.0	22		30		
11/7	15	7.3	72		1.7	27300*			7.0	24		35		
11/8	1	6.9	69		2.8	43500*			7.0	24		40		
11/9	15°	5.5°	54°		4.5°	69500*			6.9	26°		70°		
Average	16	7.2	72		2.2	33700*				23		35		

Note: * Considering flow same as preceding upstream station.
° Not included in average due to unusual waste load.

A

- INDIVIDUAL DETERMINATIONS - PEARL RIVER SURVEY

ygen on- med ppm	pH	Alkal- inity MO ppm	Sul- fides Total as S ppm	Color ppm	TOTAL SOLIDS Total ppm	TOTAL SOLIDS Volatile ppm	TOTAL SOLIDS Total Volatile 1000#/Day	SUSPENDED SOLIDS Total ppm	SUSPENDED SOLIDS Volatile ppm	DISSOLVED SOLIDS Total ppm	DISSOLVED SOLIDS Volatile ppm
Bluff 30 miles below mouth of Bogue Lusa											
	7.0	28	<0.1	55							
	6.8	21	<0.1	60							
	7.2	34		50							
	7.1	30		50							
		28		43							
	7.0	22		30				8.8	8.8		
	7.0	24		35				10.0	9.8		
	7.0	24		40				112.0	63.2		
	6.9	26°		70°							
		23		35							

pstream station.
al waste load.

B

APPENDIX B - INDIVIDUAL DETERMINATIONS - PEARL RIVER

Date 1950	Discharge cfs	Temp. °C.	Dissolved Oxygen ppm	Dissolved Oxygen % Sat.	5-Day 20° B.O.D. ppm	5-Day 20° B.O.D. lbs/day	Immediate Oxygen Demand ppm	Oxygen Consumed ppm	pH	Alkalinity MO ppm	Sulfides Total as S ppm	Color ppm	Total ppm	Vola ppm
Station P 28 Holmes Bayou above junction with West Pearl River, 44.4 miles below mouth of Bogue Lus														
First Sampling Week														
10/23	21	6.8	76		1.1	16400*			6.6	21	<0.1	60		
10/24	21	6.8	76		1.0	14600*			6.7	24	<0.1	60		
10/25	21	7.1	79		1.4	19600*		27	7.2	28		50		
10/26	20	7.4	81		0.9	11400*			7.2	22		40		
Average	21	6.8	78		1.1	15500				24		52		
Second Sampling Week														
11/7	17	8.0	83		1.2	19300*			7.1	24		33		
11/8	17	8.0	82		1.5	23200*			7.0	22		40		
11/9	18	8.4	88		2.0	31000*			6.9	19				
Average	17	8.1	84		1.6	24500*				22		36		

* Considering flow same as preceding upstream station.

DIX B - INDIVIDUAL DETERMINATIONS - PEARL RIVER SURVEY

...e ...gen ...nd ppm	Oxygen Consumed ppm	pH	Alkalinity MO ppm	Sulfides Total as S ppm	Color ppm	TOTAL SOLIDS Total ppm	TOTAL SOLIDS Volatile ppm	TOTAL SOLIDS Total 1000#/Day	TOTAL SOLIDS Volatile 1000#/Day	SUSPENDED SOLIDS Total ppm	SUSPENDED SOLIDS Volatile ppm	DISSOLVED SOLIDS Total ppm	DISSOLVED SOLIDS Volatile ppm
Pearl River, 44.4 miles below mouth of Bogue Lusa													
		6.6	21	<0.1	60								
		6.7	24	<0.1	60								
	27	7.2	28		50								
		7.2	22		40								
			24		52								
		7.1	24		33					8.2	8.2		
		7.0	22		40					57.4	42.8		
		6.9	19							147	133		
			22		36								
...upstream station.													

B

APPENDIX C

APPENDIX C

COMPUTATIONS FOR EXTENSION OF B. O. D. AND DISSOLVED OXYGEN

CONTENTS

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ULTIMATE B. O. D. COMPUTATIONS

In order to make use of the unimolecular equations of oxygen depletion in a stream it is necessary to convert 5-day B.O.D. data to ultimate first stage carbonaceous B.O.D. Since no data were obtained for incubation periods other than five days for Pearl River samples or Gaylord waste samples it is necessary to rely on data obtained elsewhere. By adequate knowledge of the per cent of the total carbonaceous B.O.D. satisfied in the five day incubation of this type waste the ultimate carbonaceous B.O.D. can be predicted. In order to determine this per cent, samples of similar kraft paper mill wastes were incubated for periods of 3, 5, and 7 days. From this data by use of the method of moments by Thomas (Sewage Works Journal, V.22, p.1343) computations were made of the rate of B.O.D. satisfaction. The average of 21 samples gave a value of 0.171 for the reaction constant k_1 in the standard formulation. This value corresponds to a depletion of 86 per cent of the ultimate carbonaceous B.O.D. in 5 day incubation in the bottle. Using this value the 5-day 20°C. B.O.D.'s obtained in the Pearl River Survey were converted to the following tabulated values. The time of flow figures were obtained by making velocity determinations at the quarter points of river cross sections at intervals throughout the length of the river.

TABLE OF ULTIMATE B.O.D.'S

Station River Mile	Time of Flow Days	B.O.D. Remaining Pounds 10/25	10/27	10/23,24,25,26,27	11/6,7
72.4	0	77,600	110,200	83,000	84,300
70.7	0.0592	56,200	72,200	61,300	87,800
69.7	0.0866	49,100	58,400		86,000
66.5	0.1725	44,100	51,000		
63.5	0.2565	44,000	52,900	51,000	58,500
60.5	0.3508	40,700	64,000		54,900
57.5	0.4287	36,300	54,100		54,900
54.5	0.4967	39,700	34,400		49,300
51.5	0.5866	44,900	38,300		45,600
48.5	0.7030	26,300	36,700		38,400
45.5	0.8075	26,700	29,200		42,000
42.4	0.8951	18,400	30,900	21,900	43,900
39.4	0.9745				
36.4	1.0539				
33.4	1.1333				
30.4	1.2127				
27.8	1.2815	22,800		17,500	34,800
72.4**		77,100**	79,000**	79,200**	84,300**

** Computed from total plant waste and Pearl River Upstream Data, see section following

COMPUTED B.O.D. LOADINGS

Since average values of B.O.D. loadings were obtained from composite samples collected on a number of days at a later date greater accuracy will be achieved by using such values rather than those of grab samples collected at the mouth of Bogus Lusa.

The average 5-day B.O.D. load in pounds discharged at the mill was, as determined from five composite samples, 7,800 lbs. The rate of exertion of oxygen demand in the incubation bottles is taken as $k_1 = 0.171$. Therefore the ultimate carbonaceous B.O.D. would be $\frac{57800}{.86} = 67,200$

To this value must be added the ultimate carbonaceous B.O.D. in the river above Bogus Lusa.

Ultimate BOD of Wastes = 67,200

On Oct. 25

Ult. BOD above = $\frac{2464 \times 0.64 \times 5.4}{0.86} = 9920$

Total 77100

On Oct. 27

Ult.BOD = $\frac{2236 \times 0.84 \times 5.4}{0.86} =$ 11800

Total 79000

First week

Ult.BOD = $\frac{2480 \times 0.77 \times 5.4}{0.86} =$ 12000

Total 79200

Data for Nov. 6 & 7

Ult. BOD above

= $\frac{2864 \times 0.95 \times 5.4}{0.86} =$ 17100

Total 84300 lbs.

DEOXYGENATION AND REAERATION CONSTANTS

Estimation of k_1 values

Estimations of the rate of BOD exertion was obtained by fitting straight lines of best fit to data as plotted on Figure 3.

October 25 Data

"A" fit $k_1 = \frac{\text{Log } 79000 - \text{Log } 10000}{1.15}$

$= \frac{4.89763 - 4.0}{1.15}$

$= 0.78$

"B" fit $k_1 = \frac{\text{Log } 79000 - \text{Log } 10000}{1.36}$

$= \frac{4.89763 - 4}{1.36}$

$= 0.66$

Avg. $\frac{0.78 + 0.66}{2} = \frac{1.44}{2} = 0.72$

October 27 data

$k_1 = \frac{\text{Log } 79000 - \text{Log } 20.000}{1.07}$

$= \frac{4.89763 - 4.30103}{1.07}$

$= \frac{0.59660}{1.07} =$

$= 0.56$

Average for $k_1 = \frac{\text{Log } 73.000 - \text{Log } 20.000}{1.05}$

First Sampling Week

$k_1 = \frac{4.86332 - 4.30103}{1.05}$

$= \frac{0.56229}{1.05}$

$= 0.54$

Overall average - $\frac{0.182}{3} = 0.61$

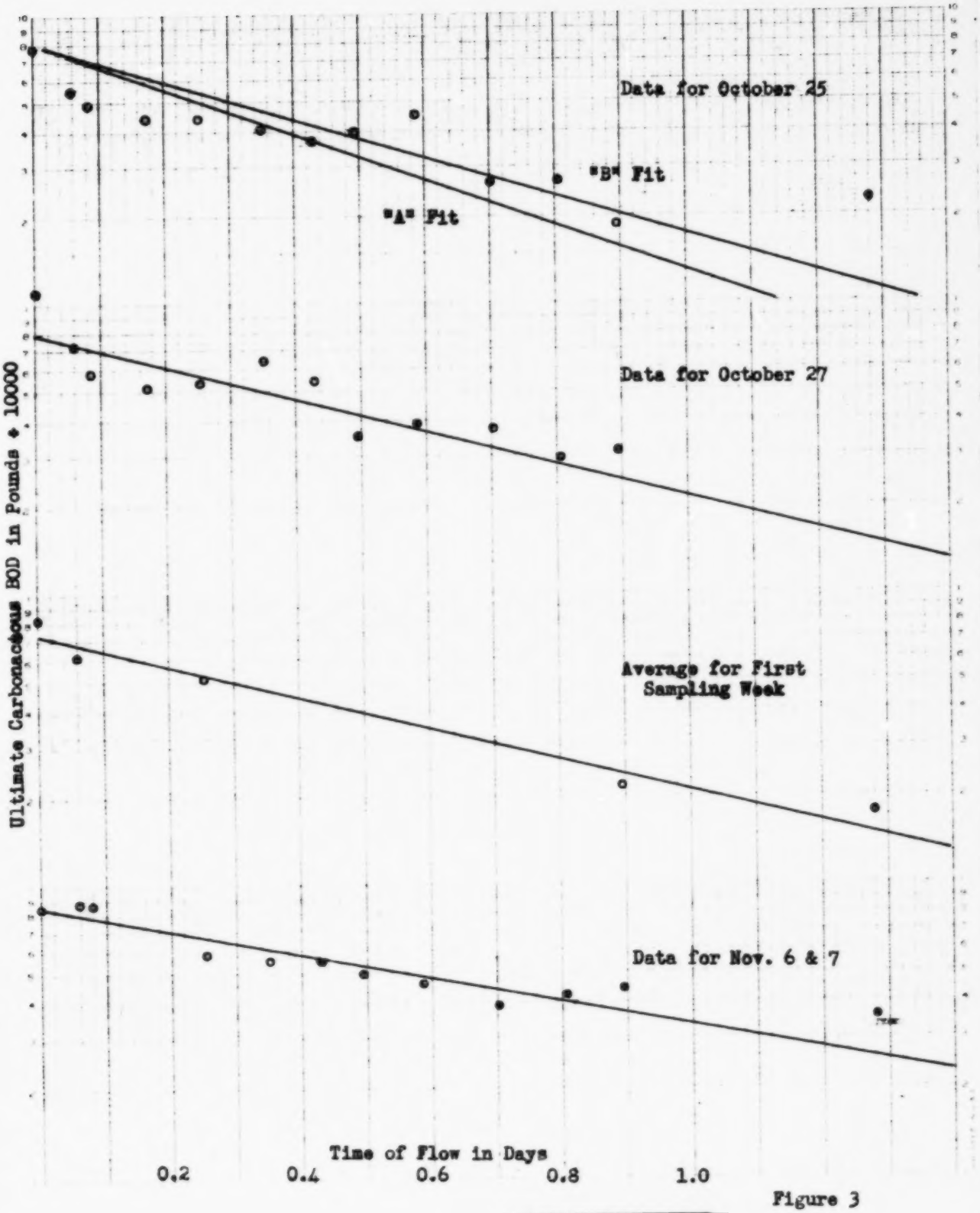


Figure 3

Reproduced from best available copy.

Data for November 6 & 7

$$k_1 = \frac{\text{Log } 84.000 - \text{Log } 22.900}{1.4}$$

$$= \frac{4.92428 - 4.35984}{1.4}$$

$$= \frac{0.56444}{1.4} = 0.403$$

Estimation of k_2 Values

Reaeration rate constants were estimated as follows:

From formula for critical deficit

$$D_c = \frac{L_a}{f} 10^{-k_1 t_c}$$

Solve for f

$$f = \frac{L_a}{D_c} 10^{-k_1 t_c} = \frac{k_2}{k_1}$$

$$k_2 = k_1 \frac{L_a}{D_c} 10^{-k_1 t_c}$$

Values of t_c and D_c are selected from DO profile data. k_1 values employed are those obtained by method of previous section.

October 25 Data

L_a = 77,100 lbs.

$$L_a = \frac{77,100 \times 1,000,000}{2520 \times 62.4 \times 86500} = 5.68 \text{ ppm}$$

D_a = 1.7 D_c = 3.5 t_c = 0.64

k_1	t_c	$k_1 t_c$	$10^{k_1 t_c}$	L_a/D_c	k_2
0.72	0.64	0.46	2.88	1.62	0.405

Data of October 27

$$L_a = \frac{18900}{2283} \times 5.4 = 6.38$$

$D_c = 3.23$ $t_c = 0.54$ days

k_1	t_c	$k_1 t_c$	$10^{k_1 t_c}$	L_a/D_c	k_2
0.56	0.54	0.302	2.005	1.97	0.55

Data for first sampling week

$$L_a = \frac{79200}{2535} \times 5.4 = 5.80$$

$D_c = 3.14$ $t_c = 0.56$

k_1	t_c	$k_1 t_c$	$10^{k_1 t_c}$	L_a/D_c	k_2
0.54	0.56	0.302	2.005	1.85	0.50

Data for November 6 & 7

$$L_a = \frac{84300}{2914 \times 5.4} = 5.36 \text{ ppm}$$

$D_a = 1.7$ $D_c = 2.84$ $t_c = 0.9$

k_1	t_c	$k_1 t_c$	$10^{k_1 t_c}$	L_a/D_c	k_2
0.403	0.9	0.3627	2.35	1.89	0.34

TABLE OF DISSOLVED OXYGEN DEFICITS

Station River Mile	Time of Flow Days	October 25 Satur ation	October 25 Pre- sent	October 25 Def.	October 27 Satur ation	October 27 Pre- sent	October 27 Def.	Average of Week Satur ation	Average of Week Pre- sent	Average of Week Def.
72.4	0	9.17	7.9	1.3	9.35	8.0	1.3	9.17	7.9*	1.3*
			7.5**	1.7**		7.3**	2.0**		7.5**	1.7**
70.7	0.0592	9.17	7.0	2.2	9.17	7.1	2.1	9.17	7.3	1.9
69.7	0.0866	9.17	6.6	2.6	9.17	7.1	2.1	9.0		
66.5	0.1725	9.0	6.3	2.7	9.17	6.4	2.7			
63.5	0.2565	9.0	6.1	2.9	9.17	5.8	3.4	9.0	6.1	2.9
60.5	0.3508	9.0	5.8	3.2	9.0	5.9	3.1			
57.5	0.4287	9.0	5.6	3.4	9.0	6.0	3.0			
54.5	0.4967	9.0	5.6	3.4	9.0	6.2	2.8			
51.5	0.5866	9.0	5.7	3.3	9.0	5.8	3.2			
48.5	0.7030	9.0	5.5	3.5	9.0	5.6	3.4			
45.5	0.8075	9.0	5.7	3.3	9.0	5.9	3.1			
42.4	0.8951	9.0	5.9	3.1	9.0	6.4	2.6	9.0	6.1	2.9
39.4	0.9745	9.0								
36.4	1.0539	9.0								
33.4	1.1333	9.0								
30.4	1.2127	9.0								
27.8	1.2815	9.0	7.1	1.9				9.0	6.8	2.2

Station River Mile	Time of Flow Days	Dissolved Oxygen Nov. 6, 1951 (and 7) * Saturation	Present	Deficit
72.4	0	10.37	8.8	1.6 1.7**
		(9.74)	(9.5)	(0.24)
70.7	0.0592	10.15	8.6	1.55
		(9.74)	(8.8)	(0.94)
69.7	0.0866	10.15	8.4	1.75
66.5	0.1725			
63.5	0.2565	10.15	7.9	2.25
		(9.74)	(7.7)	(2.04)
60.5	0.3508	9.95	7.7	2.25
57.5	0.4287	9.95	7.5	2.45
54.5	0.4967	9.95	7.5	2.45
51.5	0.5866	9.95	7.4	2.55
48.5	0.7030	9.95	7.4	2.55
45.5	0.8075	9.95	7.3	2.65
42.4	0.8951	9.95	7.0	2.95
		(10.15)	(7.3)	(2.85)
39.4	0.9745	(10.15)	(7.6)	(2.55)
36.4	1.0539	(10.15)	(7.7)	(2.45)
33.4	1.1333	(10.15)	(7.7)	(2.45)
30.4	1.2127	(10.15)	(7.9)	(2.25)
27.8	1.2815	9.95	7.4	2.55
		(10.15)	(8.0)	(2.15)

* Figures in ( ) are November 7 data.

** These figures are computed initial deficit and include immediate oxygen demand.

Immediate Oxygen Demand

The waste as it flowed from Bogue Lusa to Pearl River exerted a considerable immediate oxygen demand. For purposes of plotting the oxygen sag curve the immediate demand is subtracted from the oxygen content in the upstream sample.

October 25

ICD = 19.5 ppm in Bogue Lusa

Flow = 56 cfs

= 19.5 x 56 x 5.4 Pounds

In Pearl River = $\frac{19.5 \times 56 \times 5.4}{2520 \times 5.4}$ = 0.434 ppm

October 27

ICD = 34.5 ppm in Bogue Lusa

Flow = 47 cfs

= 34.5 x 47 x 5.4 Pounds

In Pearl River = $\frac{34.5 \times 47 \times 5.4}{2283 \times 5.4}$ = 0.7 ppm

Average for 1st Sampling Week

ICD = 17.6 ppm in Bogue Lusa Flow = 51 cfs

= 17.6 x 51 x 5.4 pounds

In Pearl River = $\frac{17.6 \times 51 \times 5.4}{2535 \times 5.4}$ = 0.35 ppm
say 0.4

November 6

ICD = 5 ppm in Bogue Lusa Flow = 50 cfs

= 50 x 5 x 5.4 Pound

In Pearl River = $\frac{50 \times 5 \times 5.4}{2914 \times 5.4}$ = 0.0859 say 0.1 ppm

Trial Filling of Oxygen Sag Formula to Data

The classical equation of the dissolved oxygen sag curve (Public Health Bulletin 146, U. S. Public Health Service 1925) and utilized by Fair (Sewage Works Journal V.11 p.445 1939) is the basis for the following computations. Symbols used are those used in references above. Actual solution is by nomograph developed by H. A. Thomas, Jr. at Harvard Graduate School of Engineering, Cambridge, Massachusetts.

Data for October 25 - Trial 1

k_1	0.72	L_a = 5.67	D_a/L_a = 0.299	
k_2	0.42	D_a = 1.7		
f	0.583			

Table of computations

t	k_2t	D_a/L_a	D_t
0			
0.2	0.084		
0.4	0.168	0.593	3.49
0.6	0.252	0.627	3.66
0.8	0.336	0.604	3.52
1.0	0.42	0.567	3.31
1.2	0.514	0.506	2.95
1.4	0.588	0.453	2.64

Trial II

$k_1 = 0.5$ $L_a = 5.83$ $D_a/L_a = 0.292$

$k_2 = 0.42$ $D_a = 1.7$

$f = 0.84$

Table of computations

t	k_2t	D_t/L_a	D_t
0	0		
0.2	0.084		
0.4	0.168	0.50	2.92
0.6	0.252	0.526	3.07
0.8	0.336	0.533	3.11
1.0	0.42	0.508	2.96
1.2	0.514	0.467	2.72
1.4	0.588	0.438	2.55

Trial III

k_1 = 0.72 L_a = 5.83 D_a/L_a = 0.292

k_2 = 0.5 D_a = 1.7

f = 0.695

t	k_2t	D_t/L_a	D_t
0	0		
0.2	0.10	0.492	2.82
0.4	0.20	0.565	3.30
0.6	0.30	0.575	3.36
0.8	0.4	0.547	3.19
1.0	0.5	0.495	2.89
1.2	0.6	0.443	2.58
1.4	0.7	0.387	2.26

Trial IV

k_1 = 0.72 L_a = 5.83 D_a/L_a = 0.292

k_2 = 0.46 D_a = 1.7

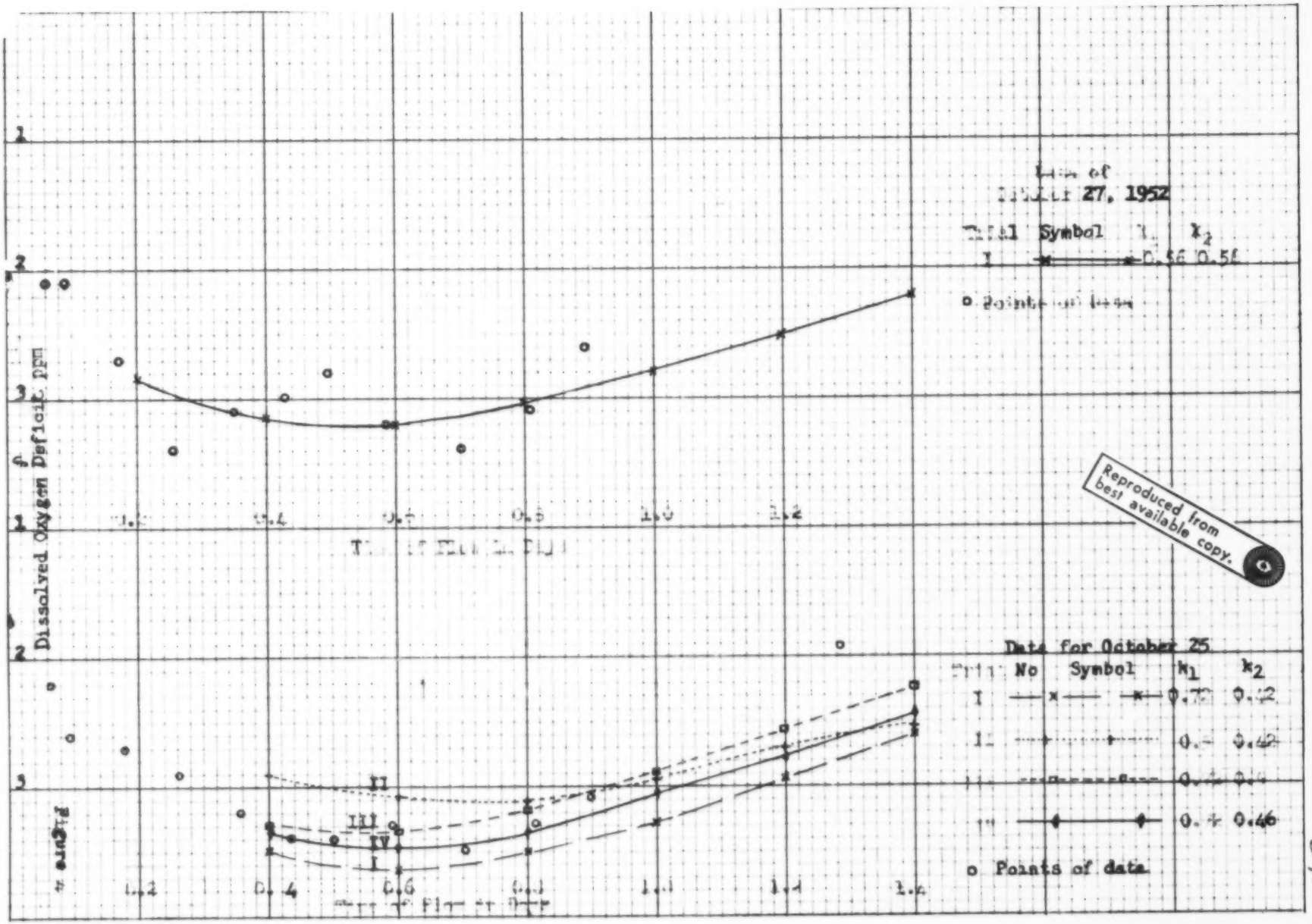
f = 0.639

t	k_2t	D_t/L_a	D_t
0	0		
0.2	0.092		
0.4	0.184	0.576	3.36
0.6	0.276	0.595	3.47
0.8	0.368	0.573	3.34
1.0	0.46	0.525	3.06
1.2	0.552	0.475	2.77
1.4	0.644	0.418	2.44

Discussion of Curve Fitting of October 25

The curve fit using values of k_1 and k_2 of Trial 1 indicate that either k_1 or k_2, or both values are too high. In Trial II k_1 was reduced considerably, in fact too much in relation to the k_2 value as shown by the curve fit. Since the curves appear too flat on the right end, k_2 is too low. In Trial III k_1 is returned to its original value of Trial I and k_2 is increased. In this curve the oxygen is not sufficiently depressed, therefore k_2 must be decreased or k_1 increased. An increase of k_1 would prevent the curve from rising on the right end so k_1 is not increased, instead k_2 is decreased.

Trial IV fits fairly well except for the right end. Actually the character of the stream change near the lower end making very possible changes in deoxygenation and aeration constants. Therefore little weight should be given to fitting the most downstream point.


Dissolved Oxygen Deficit, ppm
Data for October 27, 1952
Trial Symbol k_1 k_2
1 0.56 0.5
Points of data
Reproduced from best available copy.
Data for October 25
Trial No Symbol k_1 k_2
I 0.7 0.42
II 0.4 0.42
III 0.4 0.4
IV 0.4 0.46
Points of data
I
II
III
IV

Data for October 27 - Trial I

$k_1 = 0.56$ $L_a = 6.42$ $D_a/L_a = \frac{2.0}{6.42} = 0.312$

$k_2 = 0.56$ $D_a = 2.0$

$f = 1$

t	k_2t	D_t/L_a	D_1
0			
0.2	0.112	0.442	2.84
0.4	0.224	0.492	3.16
0.6	0.336	0.498	3.20
0.8	0.448	0.475	3.05
1.2	0.672	0.390	2.50
1.4	0.784	0.342	2.20

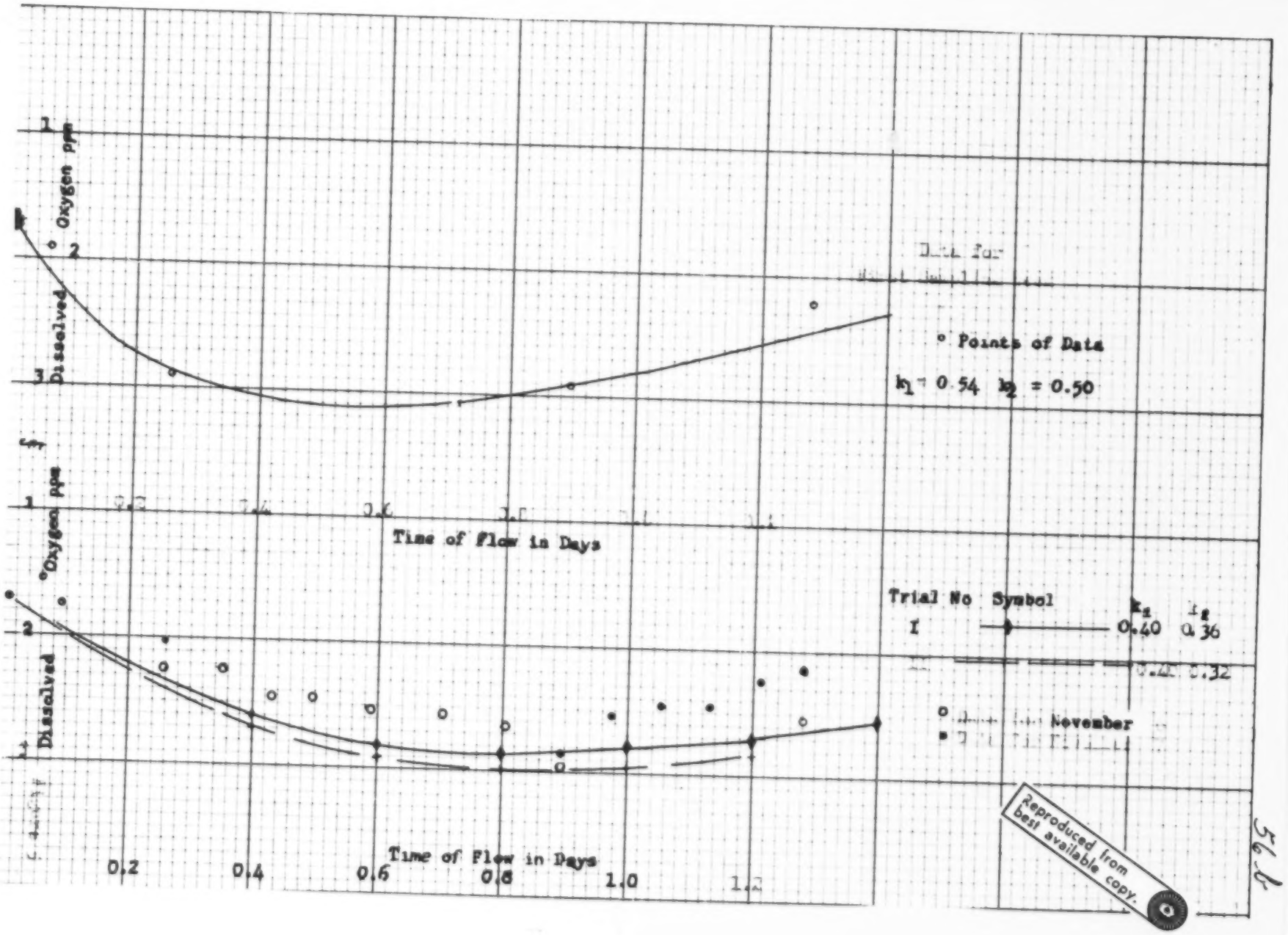
Data for First Sampling Week - Trial I

$k_1 = 0.54$ $L_a = 5.81$ $D_a/L_a = 0.342$

$k_2 = 0.50$ $D_a = 1.7$

$f = 0.926$

t	k_2t	D_t/L_a	D_t
0			
0.2	0.1	0.410	2.73
0.4	0.2	0.523	3.04
0.6	0.3	0.535	3.11
0.8	0.4	0.513	2.98
1.0	0.5	0.480	2.79
1.2	0.6	0.437	2.54
1.4	0.7	0.390	2.27



Reproduced from best available copy.

Data for October 6 and 7 - Trial I

$k_1 = 0.403$ $L_a = 5.36$ $D_a/L_a = \frac{1.7}{5.36} = 0.317$

$k_2 = 0.324$ $D_a = 1.7$

$f = 0.804$

Table of computations

t	k_2t	D_t/L_a	D_t
0			
0.02	0.0648		
0.4	0.1296	0.502	2.69
0.6	0.1944	0.540	2.90
0.8	0.2592	0.558	2.99
1.0	0.324	0.550	2.95
1.2	0.3888	0.534	2.86

Trial II

$k_1 = 0.403$ $\quad L_a = 5.36$ $\quad D_a/L_a = \frac{1.7}{5.36} = 0.317$

$k_2 = 0.36$ $\quad D_a = 1.7$

$f = 0.893$

Table of computations

t	k_2t	D_t/L_a	D_t
0			
0.2	0.072		
0.4	0.144	0.487	2.61
0.6	0.216	0.520	2.79
0.8	0.288	0.530	2.84
1.0	0.360	0.52	2.79
1.2	0.432	0.505	2.71
1.4	0.504	0.473	2.54

From the curve fitting it appears that of the values employed for k_1 and k_2, trial values used in Trial II correspond to the general trend of the curve the better.

For comparison with data gathered on other dates Trial II values are converted to 21°.

$$k_{1_{T_2}} = k_{1_{T_1}} \theta^{(T_1-T_2)}$$

$$= 0.403 \times 1.041^{(21-16)}$$

$$= 0.492$$

$$k_{2_{T_2}} = k_{2_{T_2}} (1.047)^{(21-16)}$$

$$= (0.36)(1.254) = 0.451$$

Average k_1 and k_2 values

Data	k_1	k_2	
Oct. 25	0.72	0.46	
Oct. 27	0.56	0.56	
First Week	0.54	0.50	
	1.82	1.52	
Average	0.61	0.51	$f = 0.836$
Nov. 6 & 7	0.49*	0.45*	

converted to 21°C.

* Not used in average because conversion from 16° to 21° might have appreciable error.

LOW FLOW PREDICTIONS

Records are available for years 1939 to 1948, U.S.G.S. Gaging Station at Bogalusa.

Drought flow records

Year	Drought Flow	U.S.G.S. Water Supply Paper No.
1948	1940	1112
1947	1760	1082
1946	2250	1052
1945	1880	1032
1944	1670	1002
1943	1310	972
1942	1970	952
1941	1480	922
1940	1910	892
1939	1500	872

Computations for graphical solution in accordance with method outlined in Appendix B follow:

Drought flow arranged in decreasing order	Plotting Position	Return Period 1-P	Return Period $T = \frac{1}{1-P}$
2250	0.066	0.934	1.071
1970	0.1592	0.8408	1.19
1940	0.2524	0.7476	1.34
1910	0.3456	0.6544	1.53
1880	0.4388	0.5612	1.78
1760	0.5320	0.4680	2.14
1670	0.6252	0.3748	2.67
1500	0.7184	0.2816	3.55
1480	0.8116	0.1884	5.30
1310	0.905	0.095	1 .52

Computation for pivot point of line of best fit -

Reduced variate values

2250 - -1.00
1970 - -0.61
1940 - -0.32
1910 - -0.03
1880 - +0.19
1760 - +0.48
1670 - +0.77
1500 - +1.12
1480 - +1.57
1310 - +2.28

+4.45

÷ 10 = + 0.44

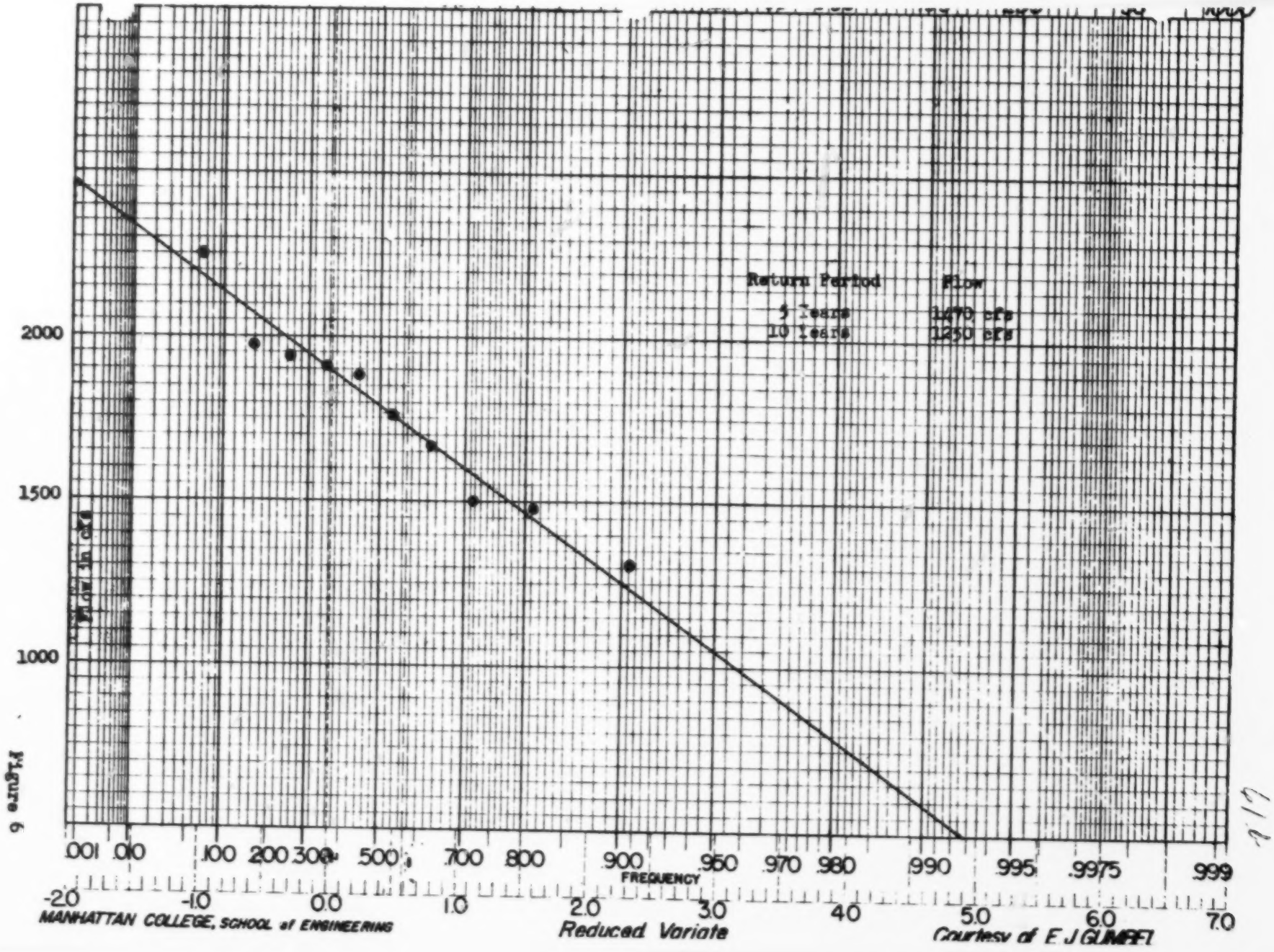

Return Period
Flow
5 Years
1470 cfs
10 Years
1250 cfs
2000
1500
1000
Flow in cfs
.001 .010 .100 .200 .300 .500 .700 .800 .900 .950 .970 .980 .990 .995 .9975 .999
FREQUENCY
-2.0 -1.0 0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0
Reduced Variate
MANHATTAN COLLEGE, SCHOOL of ENGINEERING
Courtesy of E J GUMBEL

Figure 6

9-19

OXYGEN DEPLETION PREDICTIONS

At this point the following information has been developed:

k_1 value at 21° C. = 0.61

k_2 value at 21° C. = 0.51

Predicted low flows once in 10 years - 1250 cfs

Remaining to be determined i what conditions of oxygen depletion will prevail when flows are reduced to the low likely to occur once in ten years and temperatures are up to say 28°C. The ten year flow is selected as a reasonable frequency of occurrence of damaging oxygen depletions. If pollution is abated so that damage from oxygen depletion occurs on the average of only once in ten years protection consistent with damage involved is considered to be assured.

Temperature at Critical Conditions

No data are available on high temperatures occurring in the Pearl River; however, data from other streams in the vicinity indicate that 28°C. water temperatures may be expected fairly frequen l and 30°C. temperatures are in the realm of possibility.

Initial B.O.D.

Another factor is the B.O.D. load to assume at critical times. Say the average B.O.D. for factory wastes is used - 67,200 pound ultimate. How much B.O.D. will be present in the water of Pearl River

upstream from Bogue Lusa? It might be assumed that at times of lower flow and higher temperatures inc eased rates of exertion and slower flow would result in there being lower B.O.D. concentrations upstream than that found during the survey. Another line of thought considers that since predicted flows are of the order of half of those found during the survey the pollution would receive only half as much dilution and consequently concentrations would be doubled. The assumption considered best is that B.O.D. concentrations will be about the same at lower flows as found during the survey. The pounds of B.O.D. in upstream water will be assumed as

B.O.D. upstream ultimate =

$$\frac{1250 \times 0.75}{0.86} \times 5.4 = 5900 \text{ lbs.}$$

B.O.D. plant ultimate =	67200 lbs.
Total	73100 lbs.

Initial D.O.

Another prediction has to be made concerning what state of oxygen depletion the waters upstream will be in. A conservative approach would be that they are saturated. However, since some B.O.D. is assumed as present it follows that at least a slight oxygen deficit is likely; therefore an oxygen concentration of 90% of saturation is assumed. In addition to the initial deficit these wastes were demonstrated to exert an immediate oxygen demand averaging 4850 pounds. At the assumed flow of 1250 cfs this is 0.72 ppm. Thus total initial oxygen deficit is taken as 90% of

saturation + 0.72 ppm.

For 28°C. = 7.92 (.1) + 0.72 = 1.51

B.O.D. Exertion Rate at Higher Temperatures

It is known that rate of B.O.D. exertion is increased with increase in temperature. This increase has been formulated as follows:

$$K_T = K_{20} \quad \theta^{(T-20)}$$

Reference Gotass, Sewage Works Journal, Vol. XX, p.441, 1948.

Using values proposed by previous reference

$$k_{28} = 0.61 \times 1.041^{(28-21)}$$

$$k_{28} = 0.61 \times 1.325 = 0.81$$

Reaeration Rate at Higher Temperatures

The formulation generally accepted for the effect of temperature on reaeration is the equation

$$k_{T_2} = k_{T_1} \quad \theta^{(T_2-T_1)} \quad \text{with} \quad \theta = 1.047$$

(Sewage Works Journal, Vol. 8, p. 282, 1936)

Effect of Sedimentation and Sludge Banks

In these computations it is considered that removal of B.O.D. by sedimentation is offset by contribution of B.O.D. to the stream from the bottom deposits due to biological activity.

Effect of Water Depth on Reaeration

It was assumed in these computations that the effect of variations in k_1 and k_2 with river stage would be relatively minor.

Computation of Dissolved Oxygen Sag Curve for Conditions of Drought

The classical equation of the dissolved oxygen sag curve (Public Health Bulletin 146, U. S. Public Health Service 1925) and utilized by Fair (Sewage Works Journal VII p. 445 1939) is the basis for the following computations. Symbols used are those used in references above. Actual solution is by a nomograph developed by H. A. Thomas at Harvard Graduate School of Sanitary Engineering, Cambridge, Massachusetts.

Basic Information

B.O.D. Ultimate Carbonaceous - 73100 lb.

Drought flow expected once in ten years 1250 cfs

Water temperature 28° C.

k_1 at 28° = 0.809

k_2 at 28° = 0.704

Initial D.O. = 7.92 - 1.51 = 6.41

$$f = \frac{0.704}{0.809} = 0.870$$

$$L_a = \frac{73100}{1250 \times 5.4} = 10.83 \qquad D_a/L_a = 0.592$$

Table of computations

t	k_2t	D_t/L_a	D_t	D.O.
0				6.41
0.2	0.1408	0.690	7.49	0.43
0.3	0.2112	0.693	7.51	0.41
0.4	0.2816	0.680	7.37	0.55
0.6	0.4224	0.612	6.63	1.29
0.8	0.5632	0.527	5.71	2.21
1.0	0.704	0.442	4.80	3.12
1.2	0.845	0.360	3.90	4.02
1.4	0.985			

Critical Oxygen Deficiency and Critical Time

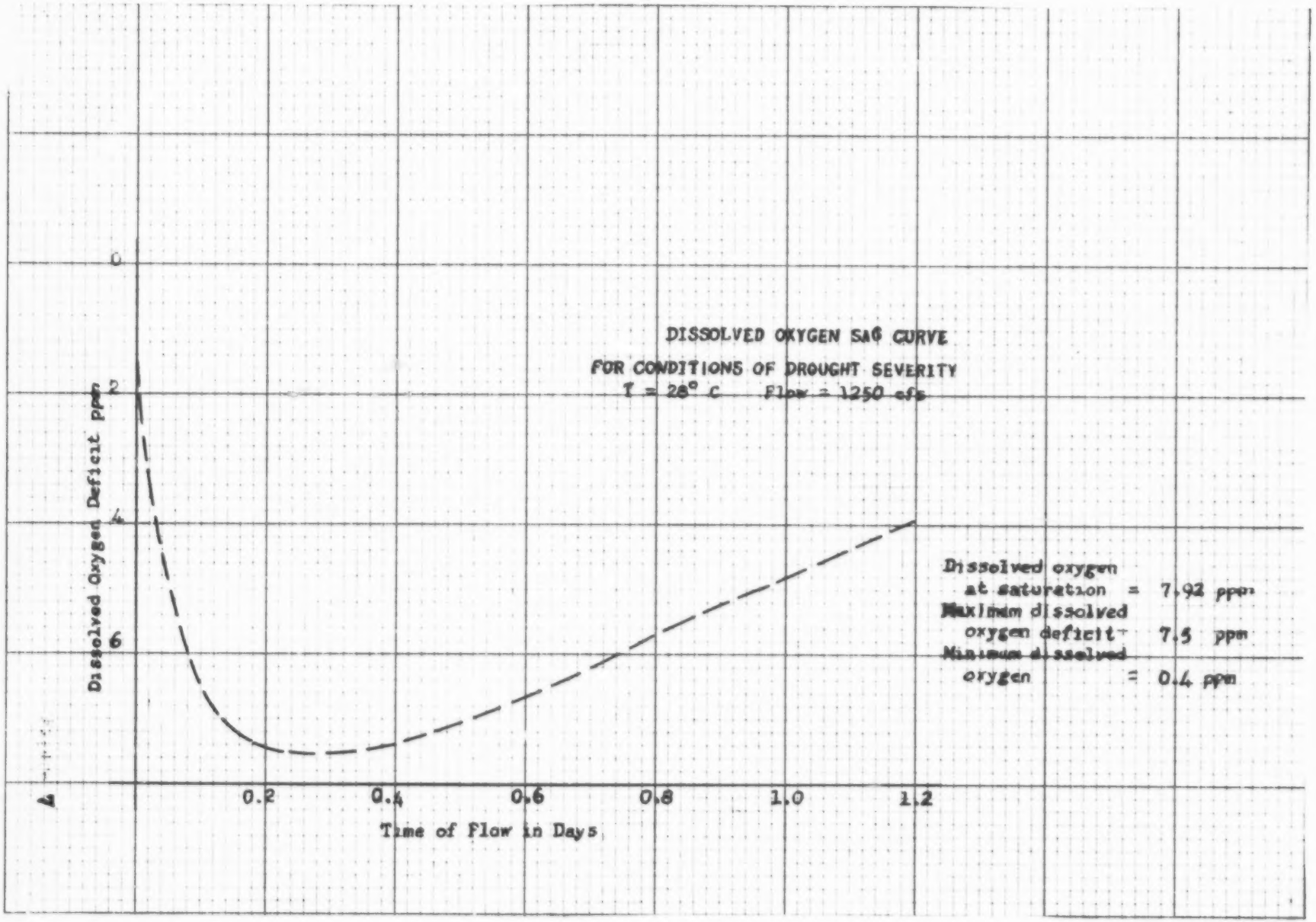
$D_a/L_a = 0.592 \qquad f = 0.870 \qquad \frac{L_a}{fs} = \frac{10.83}{(0.87)(7.92)} = 1.57$

From chart $k_1t_c = 0.218$

$t_c = \frac{0.218}{0.809} = 0.27$

From chart $\frac{D}{S} = 0.95$

$D_c = 0.95 \times 7.92 = 7.51$


DISSOLVED OXYGEN SAG CURVE
FOR CONDITIONS OF DROUGHT SEVERITY
T = 28° C Flow = 1250 cfs
Dissolved Oxygen Deficit ppm
0
2
4
6
0.2
0.4
0.6
0.8
1.0
1.2
Time of Flow in Days
Dissolved oxygen at saturation = 7.92 ppm
Maximum dissolved oxygen deficit = 7.5 ppm
Minimum dissolved oxygen = 0.4 ppm